# Journal of The Iron and Steel Institute

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*EDITOR*
K. Headlam-Morley

*MANAGING EDITOR*
E. R. Mort, B.SC., F.I.M.

*PRODUCTION EDITOR*
H. F. Cleere, B.A.

*ASSISTANT EDITOR*
Elizabeth S. Fairhurst

**EDITORIAL AND ADVERTISEMENT OFFICES**

4 Grosvenor Gardens, London, S.W.1
SLOane 0061
Telegrams - - Irosamente, Sowest

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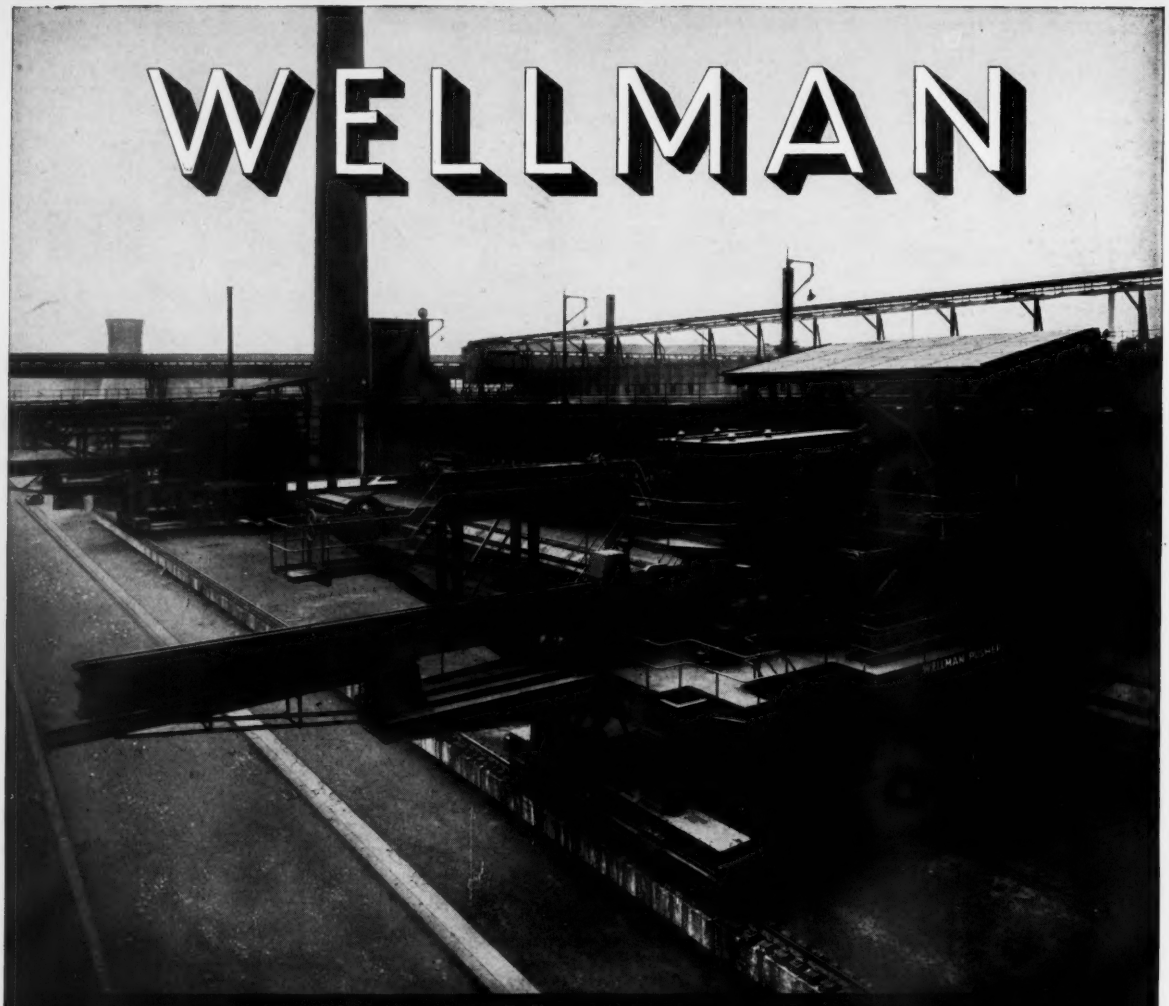
**THE IRON AND STEEL INSTITUTE, 4 GROSVENOR GARDENS, LONDON, S.W.1**

# WELLMAN



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## Dr. C. SYKES, D.Sc., Ph.D., D.Met., F.Inst.P., F.I.M., M.I.Mech.E., F.R.S.

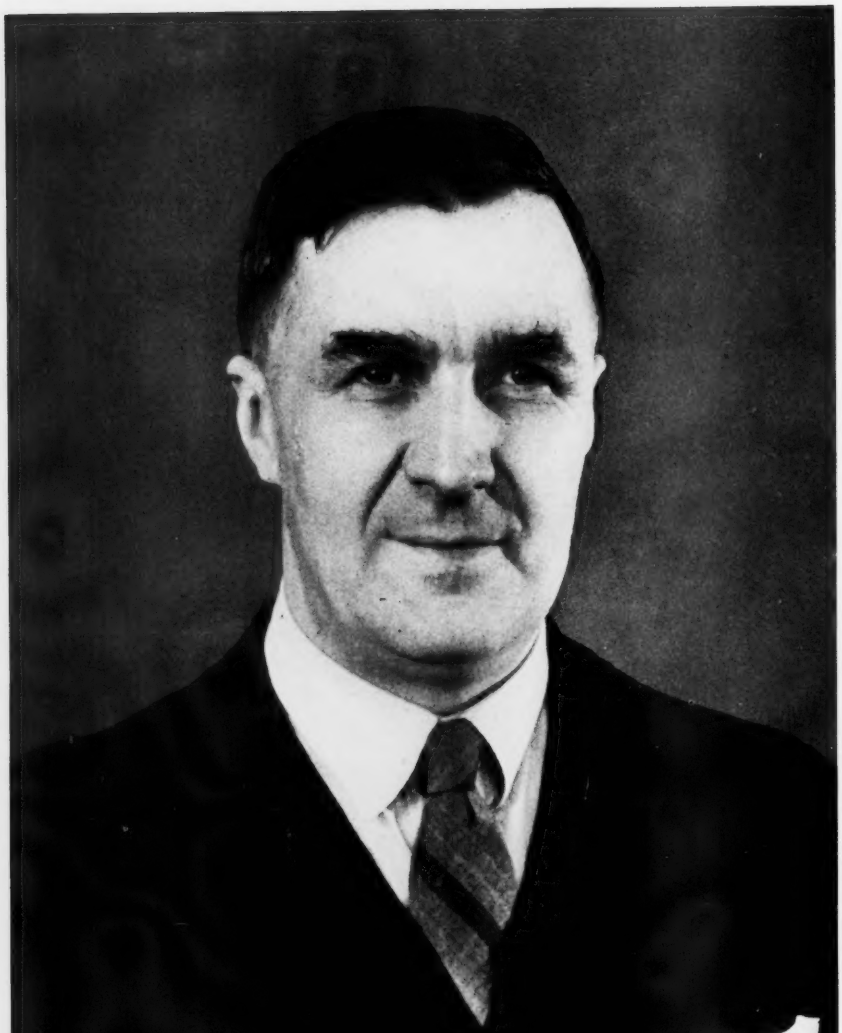
CHARLES SYKES was born on 27th February, 1905, and was educated at Staveley, Netherthorpe Grammar School, and the University of Sheffield. He graduated in science in 1925, then spent a year carrying out research in physics under Professor R. S. Milner, F.R.S. After obtaining his M.Sc. degree in 1926 he entered the Metallurgy Department of Sheffield University, under Professor C. H. Desch, F.R.S., as a Metropolitan-Vickers Research Scholar. Two papers on the alloys of zirconium (published in the *Journal of the Institute of Metals*, 1928 and 1929) represent the first fruits of his work as a metallographer.

From 1928 Dr. Sykes was connected with the research organization of the Metropolitan-Vickers Electrical Company Ltd., being engaged at first on work on high-vacuum thermionic valves and X-ray tubes. In about 1934, under the influence of Professor W. L. Bragg, F.R.S., he began to publish (in the *Proceedings of the Royal Society* and the *Journal of The Iron and Steel Institute*, and later in the *Proceedings of the Physical Society* and the *Journal of the Institute of Metals*) a remarkable series of papers on the superlattice, the order/disorder change in beta brass and other alloys, the supposed low-temperature critical points in iron and steel, and age-hardening. Some sixteen papers, all of real importance, represent the contribution that Dr. Sykes made in little more than five years to that field of knowledge which is concerned with the physics of the metallic state.

In 1940 Dr. Sykes succeeded Dr. Desch as Superintendent of the Metallurgy Division of the National Physical Laboratory, Teddington, and during the war he was engaged on a variety of problems concerning ballistics, armour-piercing shot, armour plate, and the sabot shell. He became Director of the Brown-Firth Research Laboratories in 1944, in succession to the late Dr. W. H. Hatfield, F.R.S. In 1951 he was appointed Managing Director of Thos. Firth and John Brown Ltd., which appointment he still holds.

Dr. Sykes was President of the Institute of Physics in 1953 and 1954, and at the present time is a member of the Advisory Council on Scientific Research and of its sub-committees—the Scientific Grants Committee and the Industrial Grants Committee. He was awarded the Honorary Degree of Doctor of Metallurgy by the University of Sheffield in 1955.

Elected a Member of The Iron and Steel Institute in 1940, Dr. Sykes became a Member of Council in February, 1947. He was awarded the Bessemer Gold Medal in 1956.



**Dr. Charles Sykes, D.Sc., D.Met., F.I.M., F.Inst.P., F.R.S.**

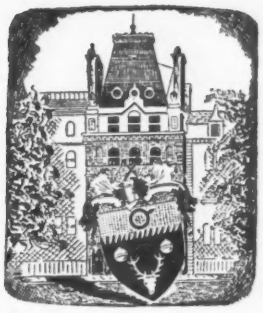
*Member of Council*

**Bessemer Medallist, 1956**

*PROCEEDINGS OF*

*THE INSTITUTE*

**Reports of Council · Meetings · Notices**



# REPORT OF COUNCIL FOR 1955

THE COUNCIL submit this, their Annual Report and Statement of Accounts for the year 1955, to Members for their approval at the 87th Annual General Meeting of The Iron and Steel Institute.

The Annual and Autumn General Meetings were held in London in April and November and there was a Special Meeting of outstanding interest in Scunthorpe in October. The Engineers' Group met on four occasions and a number of joint meetings were organized with Affiliated Local Societies and other institutions.

The Joint Metallurgical Societies Meeting in Europe 1955 was held in June in association with the American Institute of Mining and Metallurgical Engineers and the American Society for Metals. The section in Great Britain, which lasted from 1st to 7th June, was organized by the Institute and The Institute of Metals. H.R.H. the Duke of Edinburgh was Patron. The President, Sir Charles Bruce-Gardner, BT., was Chairman at the Opening Plenary Session held at Church House, Westminster, when he was supported by the President of The Institute of Metals. Other sections of the Meeting were held in Germany (at Düsseldorf), in Belgium (at Liège), and in France (headquarters in Paris) and were organized by the metallurgical societies of these countries.

The Secretary of the Institute was Honorary Joint Secretary of the European Committee which had general responsibility for all the arrangements.

In view of the exceptional character of this Meeting, which is believed to be the only occasion on which these American societies have accepted invitations to join in meetings in Europe, a fuller account is given in an Appendix to this report.

## ROLL OF THE INSTITUTE

The total membership at 31st December was 5002 compared with 4944 at 31st December, 1954. This is the first time in the history of the Institute that the total membership has exceeded 5000.

During the year, 265 Ordinary and 68 Associate Members were elected or reinstated. The deaths of 50 were reported; 158 resigned, 62 were struck off the Roll of Members, and 5 elections lapsed for non-payment of subscriptions.

An analysis of the membership at 31st December, 1955, is given in Table I, and the membership trend since the Institute was founded is shown in Fig. 1.

## OBITUARY

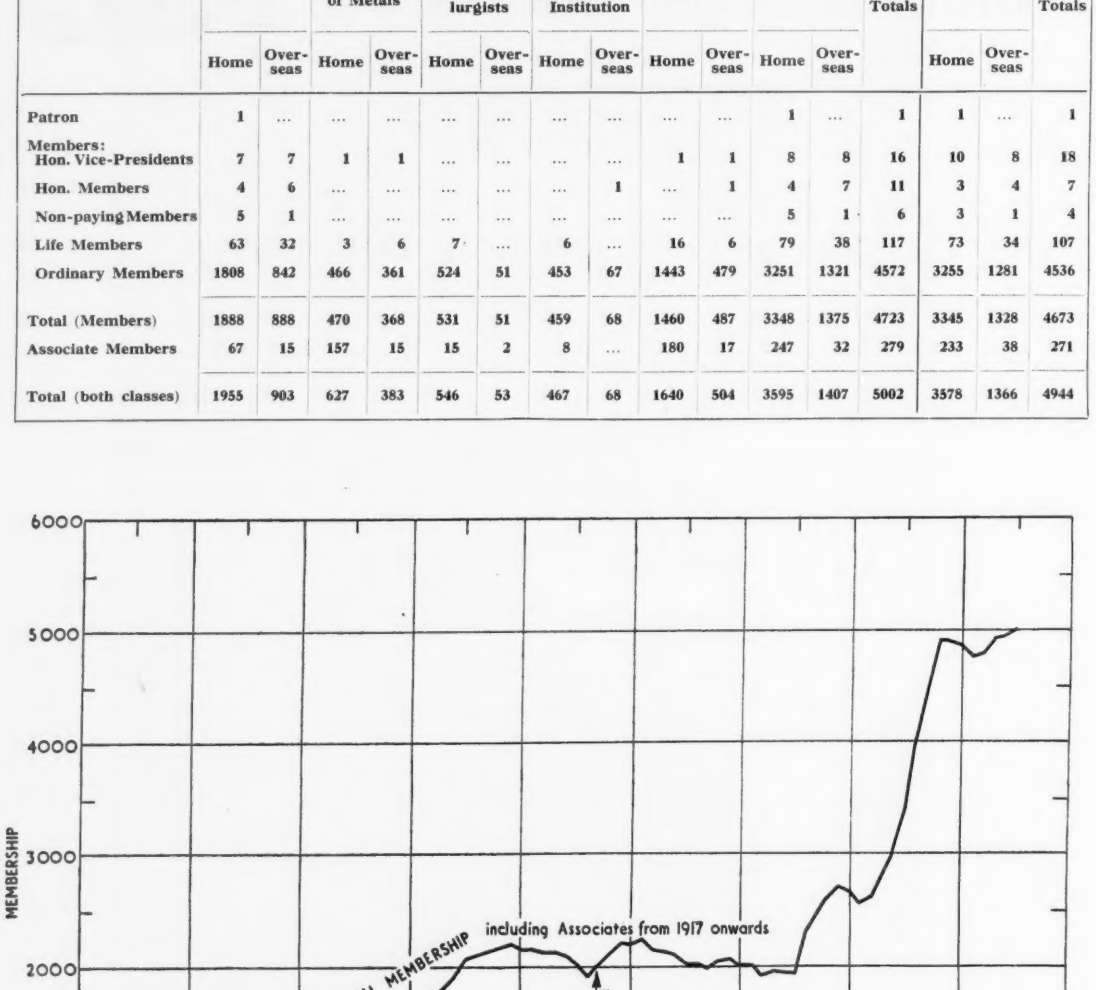
The Council regret to announce the deaths of the following 50 Members which were reported during 1955:

| | |
|---|---|
| ABLETT, C. A. (King's Lynn) | 18th July, 1955 |
| BAKER, E. (Sheffield) | 11th October, 1955 |
| BARREIRO, L. (Bilbao) | February, 1955 |
| BELAIEW, N. T. (Paris) | 5th November, 1955 |
| BERGMAN, J. (Corby) | 20th May, 1955 |
| BONELLE, T. (St. Briavels) | 1st February, 1955 |
| BURTON, N. (Knutsford) | May, 1954 |
| BUSH, R. T. (London) | 16th March, 1955 |
| CARNEGIE, H. S. (Stafford) | 4th February, 1955 |
| CONNOR, F. G. (London) | 28th February, 1955 |
| COTTAM, H. D. (Rotherham) | 3rd November, 1954 |
| DAVIES, S. G. (Scunthorpe) | Not known |
| DIMMOCK, R. H. (Llanelly) | September, 1954 |
| ELCOCK, E. W. (Edale, Sheffield) | 29th December, 1954 |
| EVANS, E. C. (Stanmore) | 17th December, 1955 |
| EVANS, H. (Solihull) | 11th September, 1955 |
| GARDNER, F. (Thornton Heath) | 19th December, 1954 |
| GARDNER, K. C. (Pittsburgh, Pa., U.S.A.) | 15th April, 1955 |
| HAMPTON, J. S. (Billingham) | 5th May, 1955 |
| KERSHAW, W. (Bolton) | Not known |
| KING, E. G. (London) | Not known |
| LANE, R. B. (Que Que, S. Rhodesia) | 18th September, 1955 |
| LAVER, H. V. (Gary, Ind., U.S.A.) | Not known |
| LOMAS, G. A. (Thirsk) | 10th April, 1955 |
| LONES, J. H. (Abergavenny) | 29th December, 1954 |
| MOSS, W. E. (Port Talbot) | 1st September, 1955 |
| NEAD, J. H. (Chesterton, Ind., U.S.A.) | 13th September, 1954 |
| NIGHTINGALE, J. (Whitehaven) | 5th November, 1955 |
| ORR, C. W. (Vancluse, N.S.W., Australia) | 3rd October, 1954 |
| PARKIN, F. M. (Sheffield) | November, 1953 |

## Table I

### MEMBERSHIP OF THE IRON AND STEEL INSTITUTE at 31st DECEMBER, 1955 AND COMPARISON WITH 1954

| | Membership at 31st December, 1955 | | | | | | | | | | | | | 1954 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ordinary Membership | | Joint Membership with | | | | | | | | Total Membership | | Grand Totals | Total Membership | | Grand Totals |
| | | | Institute of Metals | | Institution of Metallurgists | | Both Institute and Institution | | Totals | | | | | | | |
| | Home | Overseas | Home | Overseas | Home | Overseas | Home | Overseas | Home | Overseas | Home | Overseas | | Home | Overseas | |
| Patron | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 1 | 1 | ... | 1 |
| Members: | | | | | | | | | | | | | | | | |
| Hon. Vice-Presidents | 7 | 7 | 1 | 1 | ... | ... | ... | ... | 1 | 1 | 8 | 8 | 16 | 10 | 8 | 18 |
| Hon. Members | 4 | 6 | ... | ... | ... | ... | ... | 1 | ... | 1 | 4 | 7 | 11 | 3 | 4 | 7 |
| Non-paying Members | 5 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | 5 | 1 | 6 | 3 | 1 | 4 |
| Life Members | 63 | 32 | 3 | 6 | 7 | ... | 6 | ... | 16 | 6 | 79 | 38 | 117 | 73 | 34 | 107 |
| Ordinary Members | 1808 | 842 | 466 | 361 | 524 | 51 | 453 | 67 | 1443 | 479 | 3251 | 1321 | 4572 | 3255 | 1281 | 4536 |
| Total (Members) | 1888 | 888 | 470 | 368 | 531 | 51 | 459 | 68 | 1460 | 487 | 3348 | 1375 | 4723 | 3345 | 1328 | 4673 |
| Associate Members | 67 | 15 | 157 | 15 | 15 | 2 | 8 | ... | 180 | 17 | 247 | 32 | 279 | 233 | 38 | 271 |
| Total (both classes) | 1955 | 903 | 627 | 383 | 546 | 53 | 467 | 68 | 1640 | 504 | 3595 | 1407 | 5002 | 3578 | 1366 | 4944 |




*Note:* The Associate class was renamed Associate Member in 1949

**Fig. 1—Variation in Membership since the foundation of the Institute in 1869**

| | |
|---|---|
| PATRICK, J. (London) | 16th February, 1955 |
| PEARCE, H. R. (Altrincham) | 15th September, 1955 |
| POWER, A. E. (London) | 1st January, 1955 |
| RYLANDS, P. K. (Warrington) | 2nd May, 1955 |
| SANKEY, H. B. (Bilston) | Not known |
| SAUNDERS, H. L. (London) | October, 1955 |
| SEALEY, E. (Oldbury) | November, 1954 |
| SIMON, J. C. (Chesterfield) | 6th March, 1954 |
| THOMAS, E. J. (Swansea) | July, 1955 |
| THOMAS, J. H. (London) | Not known |
| TOWLER, J. H. (Leeds) | 6th April, 1955 |
| TROXELL, G. B. (Bethlehem, Pa., U.S.A.) | 7th August, 1955 |
| VOLD, O. I. (Bergen, Norway) | 6th December, 1954 |
| WAITE, J. (North Adelaide, Australia) | 2nd September, 1954 |
| WALKER, A. (Newcastle, Staffs.) | 10th July, 1955 |
| WENDEL, H. de (Hayange, France) | Not known |
| WILKS, L. P. (West Bromwich) | 21st May, 1954 |
| WILLIAMS, H. W. (Church Stretton) | 21st August, 1955 |
| WILLS, W. R. (Ruddington) | 8th September, 1955 |
| WOLF, M. A. (Birmingham) | 23rd February, 1954 |

Captain C. A. Ablett, O.B.E., had been a Member since 1908 and was elected an Honorary Vice-President in 1949; he was the founder of the Prize for a paper on engineering which bears his name. Colonel N. T. Belaiew, C.B., joined the Institute in 1912 and was Bessemer Gold Medallist in 1937. Mr. E. Baker and Mr. F. M. Parkin had been Members of the Institute since 1905 and Mr. H. de Wendel since 1909. Mr. L. Barreiro, who became a Member of the Institute in 1922, took a leading part in organizing the visit of the Institute to Spain in 1928 and since then had been active in maintaining the connection with Spanish Members. Mr. E. C. Evans, a Member since 1923, had served as Head of the Technical Department of the British Iron and Steel Federation.

## DISTINCTIONS CONFERRED IN CONNECTION WITH THE JOINT METALLURGICAL SOCIETIES MEETING IN EUROPE, 1955

### Belgian Decoration for the Secretary

His Majesty King Baudouin of the Belgians was in December graciously pleased to confer upon Mr. Kenneth Headlam-Morley, Secretary and Honorary Joint Secretary of the European Committee of the Meeting, the decoration of Chevalier de l'Ordre de la Couronne.

### Honorary Members of the Institute

The Council elected the following to be Honorary Members of the Institute in June:

Dr. Howard Biers, Consulting Engineer and a Member of both the American and European Committees of the Meeting.

Mr. William H. Eisenman, Secretary of the American Society for Metals.

Dr. Ernest O. Kirkendall, Secretary of the American Institute of Mining and Metallurgical Engineers and Honorary Secretary of the American Committee of the Meeting.

### Honorary Membership of American Societies

The President, Sir Charles Bruce-Gardner, BT., and the Secretary, Mr. K. Headlam-Morley, were elected to Honorary Memberships in the American Institute of Mining and Metallurgical Engineers and the American Society for Metals in June.

### Honorary Membership of Belgian Society

Mr. K. Headlam-Morley was elected to be an Honorary Member of the Association des Ingénieurs Sortis de l'École de Liège in June.

### Scrolls of Honour

Scrolls of Honour under Seal of the Institute and of The Institute of Metals were awarded to forty-six representatives of the American and European Societies in order to commemorate their important contribution to the Meeting, as well as to the Secretary of the Institute and to Lt. Col. S. C. Guillan, Secretary of The Institute of Metals. A list of the names of recipients is given on p. 290 of the *Journal* for December, 1955.

### Other Awards

A complete list of distinctions awarded to some of the American and European participants in the meeting by The Institute of Metals and by Institutes on the Continent as well as a list of Members of these European Institutes who were elected to Honorary Memberships in the American Societies is given on pp. 289–290 of the *Journal* for December, 1955 (vol. 182), and on p. 93 of the *Journal* for January, 1956 (vol. 183).

## VEREIN DEUTSCHER EISENHÜTTENLEUTE

Mr. Kenneth Headlam-Morley, Secretary, was elected to be an Honorary Member of the Verein deutscher Eisenhüttenleute at the Annual General Meeting held in Dusseldorf in November.

## CHANGES ON THE COUNCIL

### President-Elect

It was announced at the Autumn General Meeting, 1955, that the Council had unanimously decided to nominate Dr. H. H. Burton, C.B.E., for election as President at the Annual General Meeting, 1956, to hold office for one year.

### Other Changes

During 1955 Mr. W. F. Cartwright was elected a Vice-President and Mr. W. C. Bell was elected a Member of Council.

Dr. Maurice Cook, F.I.M., President of The Institute of Metals, agreed to serve as an Honorary Member of Council during his period of office, following Dr. S. F. Dorey, C.B.E., F.R.S.

The following agreed to serve as Honorary Members of Council during their Presidencies of the Affiliated Local Societies named; Mr. H. H. Utley (Cleveland Institution of Engineers, following Mr. H. M. Morgan); Mr. J. F. Smith (Ebbw Vale Metallurgical Society, following Mr. J. J. Beese); Mr. C. Breckon (Leeds Metallurgical Society, following Mr. C. E. Burrell); Mr. C. J. Bushrod (Manchester Metallurgical Society, following Mr. J. D. Hannah); Mr. R. L. Willott, D.S.O., O.B.E. (North Wales Metallurgical Society, following Mr. E. Taylor-Austin); Mr. T. H. Arnold (Sheffield Metallurgical Association, following Mr. F. H. Saniter); Mr. R. W. Evans (Swansea and District Metallurgical Society, following Professor H. O'Neill).

Mr. S. Thomson, who is a Member of Council, serves also as an Honorary Member of Council during his term of office as President of the West of Scotland Iron and Steel Institute (following Mr. A. McKendrick, M.C.).

In accordance with Bye-law 10, the following names of Vice-Presidents and Members of Council due to retire at the Annual General Meeting, 1956, were announced at the Autumn General Meeting, 1955:

*Vice-Presidents:* Mr. I. F. L. Elliot, Mr. N. H. Rollason, and Mr. G. Steel.

*Members of Council:* Mr. H. Boot, Mr. G. H. Johnson, Mr. D. A. Oliver, C.B.E., Dr. C. Sykes, F.R.S., and Mr. C. H. T. Williams.

(Mr. H. Boot has since died.)

No other Members having been nominated up to one month before the Annual General Meeting, the retiring Vice-Presidents and other Members of Council named above are presented for re-election.

## AWARDS AND PRIZES

The *Bessemer Gold Medal* for 1955 was awarded to Professor John Chipman, Head of the Department of Metallurgy, Massachusetts Institute of Technology, in recognition of his distinguished contributions to the knowledge of the physical chemistry of steelmaking.

The *Sir Robert Hadfield Medal* for 1955 was awarded to Mr. Tor Fjalar Holmberg, of Oy Vuoksenniska Ab., in recognition of his meritorious service in improving the technique of the production of iron and steel at the Imatra Works, Finland.

An *Andrew Carnegie Silver Medal* for 1954 was awarded to Dr. B. Cina, of the Brown-Firth Research Laboratories, in respect of research at Sheffield University and a paper on "The Effect of Cold Work on the Gamma→Alpha Transformation in some Fe–Ni–Cr Alloys" (*Journal*, 1954, vol. 177, August, pp. 406–422).

Three *Williams Prizes* for 1954 (value £100 each) were awarded to Mr. W. Jackson (Appleby-Frodingham Steel Co.) for his paper on "Use of Coke-Oven Gas and Pitch-Creosote Firing on Tilting Furnaces" (*Journal*, 1954, vol. 178, December, pp. 378–390); to Mr. R. McDonald (Colvilles Ltd.) for his paper on "Steelworks Waste Heat Boiler Practice" (*Journal*, 1954, vol. 176, January, pp. 71–92); and to Mr. A. Stirling (Stewarts and Lloyds Ltd.) for his paper on "The Pelletizing of Northampton Sand Ironstones by Vacuum Extrusion" (*Journal*, 1954, vol. 177, May, pp. 25–42).

No *Ablett Prize* was awarded for 1954.

## ANDREW CARNEGIE SCHOLARSHIPS

The following awards were made from the Andrew Carnegie Research Fund during 1955:

A. S. Appleton (Liverpool University): A second grant of £200 for research on the kinetics of first-stage graphitization in high-carbon Fe–C and Fe–Co–C alloys, together with subsidiary diffiusion experiments on Fe–C–Si and the above alloys.

C. J. Ball (Queen's College, Cambridge): A second grant of £410 for research on the plastic deformation of metals.

J. W. Barton (Liverpool University): £400 for research on the use of paraffin wax to simulate strain patterns during the plastic deformation of metals.

L. Stibe (Cambridge University): £500 for research on form changes in solid phases.

G. Summer (Manchester University): £400 for research on the amplitude-dependent damping capacity of mild steel.

P. R. Vaughan Evans (University College, Swansea): A second grant of £400 for research on the mechanical properties and internal stresses of various strip steels after various isothermal treatments.

## MOND NICKEL FELLOWSHIPS

Mr. F. H. Saniter continued to represent the Institute on the Mond Nickel Fellowships Committee.

The Committee made the following awards for 1955:

D. H. Butler (The Phosphor Bronze Co., Ltd.) to study production of copper and its alloys with particular reference to foundry methods, in the United Kingdom, on the Continent of Europe, and in America.

R. W. N. Dron (Rhoanglo Mine Services Ltd.) to study the organization of research and its relation to production in extraction metallurgy in the United Kingdom and North America.

W. F. Duncan (The British Aluminium Co., Ltd.) to study the design, layout, and operation of continuous strip mills, considering in particular metal behaviour, properties, and quality, roll lubrication and cooling, and the development of automatic controls.

R. H. Hannaford (British Iron and Steel Research Association) to study organization and practice in the ferrous foundry industry in the United Kingdom, Europe, and the United States, with particular reference to layout, mechanization, and the application of management techniques.

R. J. Harbord (John Lysaght's Scunthorpe Works Ltd.) to study the development of continuous casting in the non-ferrous industry and its application to the production of steel.

The Institute continued to provide secretarial services for the Mond Nickel Fellowships Committee.

## MEETINGS

### Annual General Meeting

The 86th Annual General Meeting was held in London on Wednesday and Thursday, 27th and 28th April, 1955, at the offices of the Institute. After the Report of Council and Accounts for 1954 had been approved and other official business transacted, new Members were elected. The Honourable R. G. Lyttelton then inducted Sir Charles Bruce-Gardner, Bt., M.I.Mech.E., into the Chair. The new President delivered his Presidential Address on "Our Industry—Decline and Recovery 1910–1933" (*Journal*, 1955, vol. 180, May, pp. 1–12). The proceedings of the meeting are recorded on pp. 321–323 of the *Journal* for August, 1955 (vol. 180).

A Dinner for Members was held at Grosvenor House, Park Lane, W.1, on Wednesday, 27th April, at which the Rt. Hon. Viscount Swinton, G.B.E., C.H., M.C., was the principal guest.

A number of Members from overseas and their Ladies accepted invitations to take part in the meeting. These invitations were issued by the Council in an attempt to repay in some small degree the hospitality received in the Netherlands, in Sweden, and in Finland during meetings held in 1953 and 1954.

A reception was held at 4 Grosvenor Gardens on the evening of Tuesday, 26th April, and the special programme included also sightseeing in and near London and entertainment for the Ladies. After the end of the meeting in London the visitors divided into three parties. One of these spent a few days in Scotland, another went to Sheffield and a third to South Wales. During these visits they were the guests of local steel companies. The Council wish to record their thanks to these companies for the generous hospitality they provided.

### Special Meeting in Scunthorpe

A Special Meeting was held in Scunthorpe from 12th to 14th October by invitation of the President, Lt.-Com. G. W. Wells, R.N. (Retd.), and Council of The Lincolnshire Iron and Steel Institute. A Ladies Committee was formed in Scunthorpe under the chairmanship of Mrs. Wells.

The programme included visits to the local iron and steel works and to an ironstone mine. A reception was given by invitation of the Mayor and Corporation and a banquet and dance were arranged by The Lincolnshire Iron and Steel Institute. Technical sessions were held at which six papers dealing with developments at works and mines in Lincolnshire were presented and discussed; the papers were published in the issues of the *Journal* for September and October, 1955.

Members and Ladies attending the meeting stayed in Scunthorpe, Lincoln, Doncaster, and Barnby Moor and

other places in the district. About 450 Members and Ladies took part.

The Council wish to express their thanks to those without whose help the meeting could not have been successfully carried out. They record their thanks especially to the President and Council of The Lincolnshire Iron and Steel Institute; to the Mayor and Corporation of Scunthorpe ; to the Chairman and Members of the Ladies Committee ; to the directors of the works who entertained Members and Ladies; to the authors of papers; and to all others who collaborated in organizing the meeting.

At the opening session the Hon. R. G. Lyttelton, Past-President, presented the Sir Robert Hadfield Medal for 1955 to Mr. Tor Fjalar Holmberg of Oy Vuoksenniska Ab., Finland.

A short account of the meeting was published on pp. 1 and 2 of the *Journal* for January, 1956 (vol. 182). A report on the technical sessions is published in this issue (pp. 69–81).

### Autumn Meeting

*Technical Sessions*

The Autumn General Meeting was held at the Offices of the Institute on Wednesday and Thursday, 16th and 17th November, 1955. The President, Sir Charles Bruce-Gardner, BT., was in the Chair on Wednesday, 16th, and the Hon. R. G. Lyttelton, Past-President, on Thursday, 17th. The proceedings of the opening session are published in the *Journal* for February, 1956 (pp. 121–123), and a report of the discussion at the technical sessions will be published later this year.

*Lecture on " The Russian Iron and Steel Industry "*

A lecture on " The Russian Iron and Steel Industry " was given by Sir Robert Shone, C.B.E., and Mr. W. F. Cartwright at the Seymour Hall, St. Marylebone, London W.1, on the evening of Wednesday, 16th November, 1955. Approximately 700 people attended. The President, Sir Charles Bruce-Gardner, BT., was in the Chair.

Sir Robert Shone, C.B.E., Executive Member of the Iron and Steel Board, was the leader of a Technical Mission consisting of experts from the British steel industry who, together with representatives from Belgium, France, and Sweden, visited Russia in 1955 under the auspices of the Economic Commission for Europe.

The other members of the British team were Mr. W. F. Cartwright, Assistant Managing Director, Steel Company of Wales Ltd., Mr. C. R. Wheeler, C.B.E., Joint Managing Director, Guest Keen Iron and Steel Co., Ltd., Mr. A. Jackson, Director and General Works Manager, Appleby-Frodingham Steel Co., and Mr. T. Dennison, Technical Officer, British Iron and Steel Federation.

The Report of the Mission has been published as Report No. 57 in the Special Report Series of the Institute.

## IRON AND STEEL ENGINEERS GROUP

Mr. W. M. Larke continued to serve as Chairman of the Iron and Steel Engineers' Group. The Engineering Committee, which organizes the activities of the Iron and Steel Engineers' Group, was composed of the following Members (from June 1955):

*Chairman*

Mr. W. M. LARKE

| | |
|---|---|
| Mr. W. H. ALVEY | Mr. N. R. D. GURNEY |
| Mr. D. R. BROWN | Mr. J. A. KILBY |
| Sir HENRY CLAY, BT. | Mr. C. E. H. MORRIS |
| Mr. T. COXON | Mr. D. E. MOXEY |
| Mr. W. A. J. DINWOODIE | Mr. J. A. PEACOCK |
| Mr. J. H. DUFFEY | Mr. G. A. PHIPPS |
| Mr. G. FOSTER | Mr. F. E. PROBYN |

Mr. C. M. SLOCOMBE

*Ex-Officio*

Sir CHARLES BRUCE-GARDNER, BT., Mr. W. BARR, Dr. H. R. MILLS

Two full-day meetings, with buffet luncheons, were held during the year: one at the offices of the Institution of Electrical Engineers and one at the offices of the Institute. The Group also held a half-day meeting in Manchester in connection with the Fuel Efficiency Exhibition at which Dr. W. S. Walker (Round Oak Steel Works Ltd.) presented a paper on " Fuel Efficiency in the Iron and Steel Industry."

A meeting of Junior Engineers was held in London from 26th to 29th September, 1955. Two papers were presented and discussed and visits were made to the Ford Motor Co., Ltd., Dagenham, and Stewarts and Lloyds Ltd., Corby. The meeting ended with a lecture by Mr. Sven Fornander (Director of Research, Jernkontoret, Stockholm) on " The Iron and Steel Industry of Sweden."

## PUBLICATIONS

The *Journal* was, as usual, published in twelve monthly parts, comprising volumes 179, 180, and 181. Indexes and binding cases are being prepared.

*Special Reports*—Three Special Reports were published: " 3rd Report of the Ingot Moulds Sub-Committee " (No. 52), " Symposium on Sinter " (No. 53), and " Developments at the Consett Works of the Consett Iron Company Ltd." (No. 54).

The Institute arranged for the publication on behalf of B.I.S.R.A. of the revised " Crane Specification for Heavy Duty Electric Overhead Travelling Cranes for Use in Iron and Steel Works."

*Bibliography*—The following bibliography was published during the year:

" Bibliography on the Rolling of Iron and Steel, including references to the Manufacture of Seamless Tubes " (*Bibliography* No. 15*A*).

This Bibliography is a continuation of No. 15 and covers the period 1948–1954.

*Translation Service*—Translations of eleven foreign technical papers (Nos. 496–506) were issued during 1955. The charge was £1 each (10*s*. for each additional copy of the same translation).

Members are asked to bring to the notice of the Secretary articles of which they need translations. In suitable cases the articles may be included in the Series; in other cases, translations can be made for Members at their own expense.

*Handbook and List of Members*, 1955—A Handbook giving information on the constitution, history, and activities of the Institute and including a List of Members was issued free to all Members early in the year.

*British Welding Journal*—The Institute continued the production of the *British Welding Journal* on behalf of The Institute of Welding and the British Welding Research Association. Appreciation was expressed by these organizations of the results achieved.

*Transactions of the Society of Instrument Technology*—The first year of the operation of the arrangements by which the Institute produced the quarterly *Transactions of the Society of Instrument Technology* has been successfully completed. The Society has expressed satisfaction at the production.

## JOINT LIBRARY AND INFORMATION DEPARTMENT

The agreement with The Institute of Metals governing the operation of the Joint Library and Information Department, which dates from 1937, expired in September, 1955. A revised agreement on similar mutually beneficial lines is being prepared.

During 1955, 232 new textbooks were acquired (268 in 1954). The Council offer their thanks to all those who have presented copies of their books and papers. Members, government departments, universities, and research laboratories have continued to make extensive use of the Library and Information Department. The number of publications borrowed was 14,416 (14,445 in 1954).

Photographic copies of documents can be provided for Members, both at home and abroad. During 1955, 172 photocopies and 66 microfilms were supplied (128 and 99 in 1954); of these, 110 photocopies and 58 microfilms were made for Members overseas.

The large number and wide variety of enquiries addressed to the Information Department continued during the year. The Department does not aim to give the sort of advice that would normally lie within the field of the metallurgical consultant, but seeks to provide the answers to enquiries by reference to the scientific and technical literature.

## BRITISH IRON AND STEEL RESEARCH ASSOCIATION

It is with great pleasure that the Council report that close co-operation has continued between the Institute and the British Iron and Steel Research Association. The Association has continued to use the Library, Information and Abstract Services and to publish many Reports in the *Journal* and in the Special Report Series.

## RELATIONS WITH OTHER SOCIETIES AND ORGANIZATIONS IN GREAT BRITAIN AND OVERSEAS

During the year co-operation and friendly relations between the Institute, The Institute of Metals, and The Institution of Metallurgists were maintained. Mutual co-operation continued with the Iron and Steel Board, with The British Iron and Steel Federation, and with The West of Scotland Iron and Steel Institute. Close relationships also continued with many scientific and technical societies at home and abroad.

### Affiliated Local Societies in Great Britain

The Sheffield Metallurgical Association became affiliated with effect from 1st January, 1955. The President for the time being of this Association has for many years served as an Honorary Member of the Council and joint meetings have frequently been held. The arrangement for affiliation was made with the full approval of The Sheffield Society of Engineers and Metallurgists.

There are now twelve Affiliated Local Societies in Great Britain as follows:

Cleveland Institution of Engineers
Ebbw Vale Metallurgical Society
Leeds Metallurgical Society
Lincolnshire Iron and Steel Institute
Liverpool Metallurgical Society
Manchester Metallurgical Society
Newport and District Metallurgical Society
North Wales Metallurgical Society
Sheffield Metallurgical Association
Sheffield Society of Engineers and Metallurgists
Staffordshire Iron and Steel Institute
Swansea and District Metallurgical Society.

As in previous years, the arrangements for affiliation included provisions by which the Institute and the Local Societies undertook to assist each other. The Institute agreed to pay to each Affiliated Local Society a capitation grant of 5*s*. per annum for each joint member, and Members of Affiliated Local Societies were entitled to pay reduced subscriptions to the Institute.

### Joint Meetings

During the year joint meetings were held between the Institute (including the Engineers Group) and the following Affiliated Local Societies: Ebbw Vale Metallurgical Society, Sheffield Society of Engineers and Metallurgists, and Swansea and District Metallurgical Society.

A joint meeting was also held with The West of Scotland Iron and Steel Institute.

### Metallurgical Societies Overseas

The number of 'kindred' societies overseas is now eighteen :

American Institute of Mining and Metallurgical Engineers
American Iron and Steel Institute
American Society for Metals
Association des Ingénieurs sortis de l'École de Liège, Belgium
Associazione Italiana di Metallurgia (Italy)
Association Luxembourgeoise des Ingénieurs et Industriels (Luxembourg)
Australian Institute of Metals
Canadian Institute of Mining and Metallurgy
Indian Institute of Metals
Instituto del Hierro y del Acero (Spain)
Jernkontoret (Sweden)
Koninklijk Instituut van Ingenieurs (Holland)
Norsk Metallurgisk Selskap (Norway)
Société Française de Métallurgie (France)
Société Royale Belge des Ingénieurs et des Industriels (Belgium)
Verein deutscher Eisenhüttenleute (Germany)
Verein Eisenhütte Oesterreich (Austria)
Verein Schweizerischer Maschinen-Industrieller (Switzerland)

Members of the Institute who are Members of, or are on the staffs of member firms of, any of the above Societies, if resident in the countries concerned, pay reduced membership subscriptions.

### Representation at Meetings

The Institute was represented by Mr. A. E. Chattin, Assistant Secretary and Librarian, at a meeting of the Historical Committee of the Verein deutscher Eisenhüttenleute which was held in May at Schaffhausen, Switzerland, in order to view the Iron Library at Kloster Paradies which is supported by Georg Fischer A.G.; at the preliminary technical meetings of the 22nd Annual Conference of the Fédération Internationale de Documentation held in Brussels in September by the Information Officer, Mr. J. P. Saville; and by the Secretary at the meetings of the Société Française de Métallurgie in Paris in October and of the Verein deutscher Eisenhüttenleute in Düsseldorf in November.

An International Congress on Documentation of Applied Chemistry was held in London in November. The Hon. R. G. Lyttelton became an Honorary Vice-President and the Secretary was a Member of the Organizing Committee and of the Finance Committee.

## PRESENTATIONS TO THE INSTITUTE

Imperial Chemical Industries Ltd. again sent, through The Institute of Metals, the sum of £21 in appreciation of

services rendered to the Company by the Joint Library.

Dr. C. H. Desch, F.R.S. (Past-President), deposited in the Joint Library the two volumes of a work by Jose Perez de Barradas entitled "Orfebreria Prehispanica de Colombia," which had been presented to him by Signor Luis-Angel Arango, General Manager of the Banco de la Republica, Bogotá, Colombia.

The Loewy Engineering Co., Ltd., presented the Library with twelve volumes of *Stahl und Eisen* for the years 1930 to 1935 inclusive in handsome bindings.

The Council offer their thanks to these donors for their generous presentations.

## EDUCATION

### The Institution of Metallurgists: Education Committee

Mr. James Mitchell, C.B.E., Past-President, is Chairman of the Education Committee of The Institution of Metallurgists. The Institute was represented on this Committee by Mr. K. Headlam-Morley and Mr. D. R. O. Thomas.

### Joint Committee on National Certificates in Metallurgy

The Institute was represented on the Joint Committee for National Certificates in Metallurgy by Mr. K. Headlam-Morley in place of Mr. D. R. O. Thomas with effect from 1st January, 1955.

### Sheffield University—Institute Prize, 1955

The Iron and Steel Institute Prize for 1955 at Sheffield University was awarded to Mr. D. J. Street, who obtained the degree of B.Met., with Honours.

## OFFICES OF THE INSTITUTE

The revised 60-year lease for the offices of the Institute at 4 Grosvenor Gardens, Westminster, S.W.1, which was purchased in 1953 from the Grosvenor Estate with contributions subscribed by the Companies listed in the Report of Council for 1953 (*Journal*, 1954, April, vol. 176, p. 344) came into effect on 25th September, 1955. The sub-lease agreed in 1938, under which The Institute of Metals occupied part of the upper storeys of the building, expired on the same date. Revised terms for a short lease on mutually acceptable terms were agreed pending the date when The Institute of Metals leave in order to occupy new premises on their own.

During 1955, substantial redecoration and renovation was carried out at 4 Grosvenor Gardens. The stonework of the front of the house was cleaned and all outside paintwork repainted. All the rooms on the first floor, the library, the main hall and staircase, and much of the basement were redecorated. The portraits were cleaned and restored and the chairs in the Council Room recovered. A new staircarpet was laid on the main staircase.

## STAFF

The Council wish to record their appreciation of the services rendered by the staff.

They regret to report that Mr. R. A. Ronnebeck, who joined the staff in 1938, died on 23rd December, 1955. Mr. Ronnebeck had been responsible for the preparation of the Abstracts Section in the *Journal*.

## HONOURS CONFERRED UPON MEMBERS

The Council offer their congratulations to all Members who have received Honours or appointments during the year. Their names have been recorded in the News section of the *Journal*.

# FINANCE

*The Accounts for* 1955 *are appended*

(Figures for the previous year are printed in brackets for comparison)

## SUMMARY

The financial position of the Institute has been well maintained although during 1955 exceptionally heavy special expenditure, amounting to £10,435, was incurred. In spite of this, income during the last seven years, from 1949 to 1955, has exceeded expenditure by an average of £1700 a year. The House Fund, formed in 1953 by subscriptions from companies in the industry, stood at £55,200 at 31/12/55.

The prospects for the next two or three years appear to be satisfactory. Income is estimated to exceed expenditure by small amounts. In spite of constantly increasing costs no increase in the subscription rates payable by Members is contemplated at present.

## GENERAL FUND

### Balance Sheet and Income and Expenditure Account

The Balance Sheet at 31st December, 1955, and the Income and Expenditure Account for the year ending on that date are submitted in the usual form.

### Income and Expenditure Account

Ordinary Income exceeded Expenditure by £2738.

'Special' expenditure consisted of: Entertainment of foreign visitors (£2099), Building Improvements (£5359), and Renovation of the furniture and Pictures in the Council Rooms (£566), a total of £8024. The Meeting in Scunthorpe resulted in a surplus of £382. The net deficit transferred to the Accumulated Fund was £4904.

### Accumulated Fund

The provisional cost of the Joint Metallurgical Societies Meeting in Europe has been written off—£2411. The accounts have not yet been completed, but since the end of the year it has been ascertained that the maximum possible additional liability is £174.

Transfers of £1750 have been made to Reserves: of £250 for the Comprehensive Index, £1000 for the House Fund, and £500 for Supplementing Staff Pensions. The Reserve for Repairs—£3000—has been brought in; as stated in last year's report, this sum was reserved to set against the cost of Building Improvements referred to above. After charging the deficit for the year, the balance of the Accumulated Fund carried to the Balance Sheet was £30,115 compared with £36,180 last year.

### House Fund—Cost of Lease Account

The value of the lease of No. 4 Grosvenor Gardens has been written down by transfer of £1000 from the Accumulated Fund as well as by the amount of interest received from investments.

## TRUST FUNDS

The accounts of the Trust Funds are presented in the usual form. More extensive use has been made of the available money, with the result that the Accumulated Funds have been reduced as follows: Andrew Carnegie Research Fund from £8340 to £7332, Williams Prize Fund from £834 to £662, and Bessemer Medal Fund from £42 to £26. The income of the Sir Robert Hadfield Fund is greater than the normal cost of providing a medal, so that the Accumulated Fund has increased from £30 to £35.

## INVESTMENTS

The market value of investments at the end of the year was, for the first time in recent years, below their cost when purchased, which is the value at which they are shown in the Balance Sheets. This reflects the general fall in the value of gilt-edged securities. The market value of the investments of the General Fund, Life Composition Fund and House Fund totalled £47,143 (£49,819) compared with a cost of £51,303 (£48,052), while the market value of the four Trust Funds was £39,303 (£42,072) compared with a cost of £40,678* (£38,145).

* This figure includes £474 15*s.* 0*d.* British Transport 30% Guaranteed Stock 1978/88 at the figure of £400, at which it is included in the Balance Sheet of the Bessemer Medal Fund.

# *JOINT METALLURGICAL SOCIETIES MEETING IN EUROPE, 1955*

The outstanding success of the First World Metallurgical Congress, held in Detroit, Michigan, U.S.A., in 1951, inspired the Board of Trustees of the American Society for Metals to examine the possibility of organizing an international gathering of metallurgists in Europe. The Congress had been sponsored by the American Society for Metals and held in conjunction with the 33rd National Metallurgical Congress and Exposition. It had been attended by " 510 overseas conferees from 39 free nations of the world." Several well-planned tours had made it possible for those who came from other countries to pay visits to works and laboratories, universities and technical colleges and thus to obtain information about American industry and research and American instructional and industrial methods before arriving at Detroit. As is usual, many prominent American scientists and technical men working in metallurgy and allied fields had taken part in the discussions which were the chief features of the Congress.

A year later, Dr. John Chipman, Past-President of the American Society for Metals, was deputed to make unofficial enquiries. The success of his journey is a tribute to his personal qualities as well as to the interest of his mission. Every European Society gave an enthusiastic reception to his proposals. Eventually it fell to The Iron and Steel Institute to take the lead. Representatives of The Institute of Metals and of the metallurgical societies of France, Germany, and Sweden met during the Annual General Meeting of the Institute in London in April, 1953. The Secretaries of the American Iron and Steel Institute (Mr. George Rose) and of the American Society for Metals (Mr. William H. Eisenman) were also present, and the American Institute of Mining and Metallurgical Engineers was represented by Mr. Howard Biers. This meeting enthusiastically but unofficially endorsed the general proposal to hold a Congress.

The summer was spent in negotiations. Official invitations to the American Societies were issued in October, 1953, in letters from the Institute which were written also on behalf of The Institute of Metals, the Société Française de Métallurgie, the Verein deutscher Eisenhüttenleute and the Deutsche Gesellschaft für Metallkunde*, and Jernkontoret. (A little later, the Centre National de Recherches Métallurgiques† joined in and from then onwards took an equal share with the other European societies in responsibility for all the arrangements.) These invitations were accepted by the American Institute of Mining and Metallurgical Engineers and the American Society for Metals. It was decided that the meeting should be held in June, 1955.

Responsibility for American representation and all arrangements in America were co-ordinated by an 'American Committee,' consisting of the Presidents, Secretaries and other representatives of the two societies. Dr. Ernest O. Kirkendall, Secretary of A.I.M.E., acted as Secretary.

Responsibility for the programmes and detailed arrangements in the United Kingdom, Germany, Belgium and France was assumed by the Societies in each of these countries. In the United Kingdom a Joint Committee was set up by The Iron and Steel Institute and the Institute of Metals. Overriding responsibility for the arrangements in Europe was entrusted to a 'European Committee' consisting of the Directors or Secretaries of the seven participating Societies. The Secretary of The Iron and Steel Institute served as Honorary General Secretary. Dr. Howard Biers was elected a member of both the American and European Committees and this proved a most helpful arrangement in maintaining liaison and community of thought. Frequent meetings of the European Committee were held in different countries, usually in conjunction with some other function which brought the members together.

Messrs. Thos. Cook and Son Ltd. were appointed Travel Agents and Managers in Europe.

The meeting was divided into four sections : from 1st to 7th June, 1955 in the United Kingdom ; and from 8th to 13th June in Germany. On 13th June there was a visit to Liège, and the concluding section was held in France from 14th to 17th June. Post-meeting tours were arranged to Austria, Italy, and Spain, with the active assistance of the Eisenhütte Österreich, the Associazione Italiana di Metallurgia, and the Instituto del Hierro y del Acero.

Full accounts have been published elsewhere and need not be repeated here. It may suffice to record that the scope was defined as covering " ironmaking (including coke and ore preparation), steelmaking, mechanical working and heat treatment, both ferrous and nonferrous (including hot and cold rolling, forging, wire drawing and continuous casting, but not the foundry industry), refining and fabrication of non-ferrous metals, heat treatment, surface treatment (including finishing and coating), metallurgical education and training in industry, and research." The objects were " to establish personal contacts between experts in the U.S.A. and in Europe, to provide opportunities for scientific and technical discussion, to enable visitors from the U.S.A. to see something of the metallurgical industries of Europe and to foster better understanding and cooperation among all concerned." These objects were fully achieved.

K. H.-M.

*Acting in conjunction with the Gesellschaft deutscher Metallhütten- und Bergleute.

†Acting also for the Association des Ingenieurs sortis de l'École de Liège.

## SELECTED REFERENCES

### The United Kingdom

*The Iron and Steel Institute:*

*Journal*, 1955, vol. 180, June: Detailed programme, biographies, and general information (pp. 201–214); papers (pp. 97–200).

*Journal*, 1955, vol. 180, July: Note on election of Dr. H. Biers, Mr. W. H. Eisenman, and Dr. E. O.

Kirkendall to Honorary Membership of The Iron and Steel Institute (p. 298).

*Ibid.*: Note on first section of the Meeting in London, and on industrial tours, 1st to 7th June. (p. 298).

*Journal*, 1955, vol. 181, December: List of Awards made in London, Düsseldorf, Liège, Paris, and Turin. (pp. 289–290).

*Journal*, 1956, vol. 182, January: Additions to List above (p. 93).

*The Institute of Metals*

*Journal*, 1954–55, vol. 83, June: Detailed programme, biographies, and general notes (pp. 249–254).

*Journal*, 1955–56, vol. 84, November: Note on election of Dr. M. Cook and Lt.-Col. S. C. Guillan to Honorary Life Memberships in the A.I.M.E. and the A.S.M.

*Other Periodicals*

*British Steelmaker*, 1955, vol. 21, July, pp. 210–225. A full description of the activities in London, with a picture supplement and a list of the overseas members.

*The Engineer*, 1955, vol. 200, Aug. 5, pp. 179–183. A note on the London meetings, and full descriptions of the German plants visited.

*Ibid.*, Aug. 12, pp. 216–219; Aug. 19, pp. 252–254. A note on the Technical Sessions in Paris, and descriptions of the French plants visited.

*Iron and Coal Trades Review*, 1955, vol. 170, June 10th, p. 1332. A report of the Technical Sessions in London.

*Iron and Coal Trades Review*, 1955, vol. 171, July 1st, pp. 31–35. Notes on industrial tours in Germany, Belgium, and France.

*Iron and Steel*, 1955, vol. 28, July, pp. 337–338. Report of the Technical Sessions in London.

*Metallurgia*, 1955, vol. 52, July, p. 36. A description of the London meeting and a list of the subjects of the Technical Sessions; mention of the social activities, and of the technical tours.

**United States of America**

*Metal Progress*, 1955, vol. 68, July, p. 5. Conferment of Honorary Membership of The Iron and Steel Institute upon Mr. W. H. Eisenman.

*Metals Review*, 1955, vol. 28, Sept., pp. 10–12. General description of the Meeting, including technical sessions, tour, and honours conferred.

*American Foundryman*, 1955, vol. 27, June, p. 104. Mention of Meeting in calendar of future events.

*Journal of Metals*, 1955, vol. 7, August, pp. 865–867. General description of the tour, by Dr. E. O. Kirkendall.

**Germany**

*Stahl und Eisen*, 1955, vol. 75, Oct. 20, p. 1357–1364. Description of the Technical Sessions in London, of the Düsseldorf meetings and the industrial visits in Germany, and reference to the sessions at Liège and in Paris.

*Erzmetall*, 1955, vol. 8, Sept., pp. 447–448. Report of the Düsseldorf meetings, and a list of the industrial visits.

*Zeitschrift für Metallkunde*, 1955, vol. 46, July, p. 521. Report of the Düsseldorf meetings.

**France**

*La Métallurgie et la Construction Mécanique*, 1955, vol. 87, Nov., 867–869. A report on the Technical Session in Paris and the industrial visits in France.

# THE IRON AND STEEL INSTITUTE

## BALANCE SHEET, 31st DECEMBER, 1955

### *General Account*

| 1954 | LIABILITIES | £ | £ |
|---|---|---|---|
| | *Accumulated Fund:* | | |
| 36,180 | Balance per Account annexed | | 30,115 |
| | *Current Liabilities and Provisions:* | | |
| 10,726 | Sundry Creditors (part estimated) | 12,541 | |
| 961 | Due to Life Composition Fund | 1,056 | |
| 2,451 | Due to House Fund | 2,030 | |
| 30 | Due to Sir Robert Hadfield Medal Fund | 35 | |
| 542 | Due to Bessemer Medal Fund | 26 | |
| 1 | Due to Williams Prize Fund | 1 | |
| 143 | Ablett Prize Fund Account | 242 | |
| 230 | Subscriptions received in advance | 476 | |
| 3,208 | Payments received in advance for Publications | 4,250 | |
| — | Andrew Carnegie Research Fund | — | |
| | Sundry Provisions as at 31st December, 1954: | | |
| 1,600 | Reserve for Comprehensive Index | 1,600 | |
| | Transfer from Accumulated Fund | 250 | 1,850 |
| | Repairs, Decorations, and Equipment | 3,000 | |
| 3,000 | Transfer to Accumulated Fund | 3,000 | — |
| | Reserve for Supplementing Staff Pensions | 1,500 | |
| 1,500 | Transfer from Accumulated Fund | 500 | |
| | | | 2,000 |
| | | | 3,850 |
| 1,478 | Bank Overdraft | | 2,836 |
| 25,870 | | | 27,343 |
| 5 | *Special Publications Suspense Account* | | |
| £62,055 | | | £57,458 |

| 1954 | ASSETS | £ | £ |
|---|---|---|---|
| | *Furniture and Fittings* | | Not valued |
| 32,982 | *Investments at Cost per Schedule* (Market value at 31st December, 1955—£30,091) | | 32,982 |
| | *Current Assets:* | | |
| 2,125 | Stock of Paper as valued by Managing Editor | 2,801 | |
| 9,921 | Sundry Debtors | 8,251 | |
| 2,777 | British Iron and Steel Research Association | — | |
| 4,596 | British Welding Journal | 5,160 | |
| — | Transactions of the Society of Instrument Technology | 1,091 | |
| 191 | Current Accounts | 133 | |
| 1,777 | Deposits and Payments in Advance | 804 | |
| 2,847 | Balance at Post Office Savings Bank and Cash in Hand | 179 | |
| 4,830 | Publishing Account—Expenditure incurred in advance on Publications | 5,466 | |
| 29,064 | | | 23,885 |
| 9 | *Joint Committee on Metallurgical Education* | | — |
| — | *Special Publications Suspense Account* | | 591 |
| £62,055 | | | £57,458 |

### *Special Funds*

| 1954 | | £ | £ |
|---|---|---|---|
| | *Life Composition Fund:* | | |
| 5,743 | Balance at 31st December, 1954 | 5,900 | |
| 154 | *Add* Compounded during 1955 | 83 | |
| 3 | *Add* Premium on Conversion of Defence Bonds | 12 | |
| 5,900 | | | 5,995 |
| | *House Fund:* | | |
| 54,450 | Amounts received from Companies | 54,450 | |
| | Amount receivable in 1954 | 750 | |
| | | | 55,200 |
| £122,405 | | | £118,653 |

| 1954 | | £ | £ |
|---|---|---|---|
| | *Life Composition Fund:* | | |
| 4,939 | Investments at Cost per Schedule (Market value at 31st December, 1955—£4,842) | 4,939 | |
| 961 | Due from General Account | 1,056 | |
| 5,900 | | | 5,995 |
| | *House Fund:* | | |
| 41,000 | Lease at Cost, *less* amounts written off, per Account annexed | 39,469 | |
| 750 | Sundry Debtor | 319 | |
| 10,131 | Investment at Cost per Schedule (Market value at 31st December, 1955—£12,210) | 13,382 | |
| 118 | Balance at Bank | — | |
| 2,451 | Due from General Fund | 2,030 | |
| 54,450 | | | 55,200 |
| £122,405 | | | £118,653 |

We have examined the above Balance Sheet of the Institute and found it to be correct.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET,
LONDON, E.C.2
*25th March*, 1956

(*Signed*) W. B. KEEN & Co.,
*Chartered Accountants*



## INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st DECEMBER, 1955

# INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1955

## EXPENDITURE

| 1954 £ | £ | | £ | £ |
|---|---|---|---|---|
| | | *Staff Expenses:* | | |
| 26,169 | | Salaries | 27,775 | |
| 468 | | National Insurance | 521 | |
| 2,964 | | Staff Superannuation Fund and Pension | 2,759 | |
| 895 | | Cost of Staff Luncheon Vouchers | 932 | |
| 30,496 | | | | 31,987 |
| | | *Other Administrative Expenses:* | | |
| 1,632 | | Printing and Stationery | 1,957 | |
| 864 | | Postage and Receipt Stamps | 1,030 | |
| 1,750 | | Travelling and Entertainment | 1,833 | |
| 1,861 | | Meetings | 672 | |
| 612 | | Telephone and Telegrams | 734 | |
| 95 | | Insurances | 133 | |
| 188 | | Audit Fee—1954 | 188 | |
| 672 | | Sundry Payments | 603 | |
| 7,674 | | | | 7,150 |
| | | *Establishment Expenses:* | | |
| 1,200 | | Rent | 1,000 | |
| 639 | | Rates | 742 | |
| 1,987 | | Cleaning, Heating, Lighting, and Water | 1,906 | |
| 476 | | Repairs and Decorations | 437 | |
| 171 | | Office Furniture and Fittings | 442 | |
| 4,473 | | | | 4,527 |
| | | *Publishing:* | | |
| 26,649 | | 1955 *Journal*—Printing, Paper, etc. | 26,659 | |
| 1,865 | | Other Publishing Activities—Expenses | 3,012 | |
| — | | Adjustments—amounts under-provided in previous year | 78 | |
| 28,514 | | | | 29,749 |
| 249 | | *Translations Service*—Preparation | | 221 |
| | | *Library and Information Department:* | | |
| 643 | | Library Books and Binding | 600 | |
| 55 | | Reviewers' Fees | 47 | |
| 901 | | Abstractors' Fees | 935 | |
| 1,599 | | | | 1,582 |
| | | *Miscellaneous:* | | |
| 1,341 | | Historical Investigator—Honorarium and Expenses | 1,318 | |
| 344 | | Contributions to Affiliated Local Societies | 256 | |
| | | Education: | | |
| 100 | | Joint Committee for National Certificates in Metallurgy | 150 | |
| 11 | | Prizes | 10 | |
| 223 | | Grants | 294 | |
| 2,019 | | | | 2,028 |
| 3,109 | | Balance carried down | | 2,738 |
| £78,133 | | | | £79,982 |
| 93 | | Cost of Special Entertainment of foreign visitors | | 2,099 |
| — | | Expenditure on Building Improvements | | 5,359 |
| — | | Renovation of Council Room Furniture and Pictures | | 566 |
| 3,330 | | Excess of Income over Expenditure for the Year | | — |
| £3,423 | | | | £8,024 |

## INCOME

| 1954 £ | £ | | £ | £ |
|---|---|---|---|---|
| | | *Subscriptions:* | | |
| 17,080 | | Current | 17,072 | |
| 470 | | Arrears | 527 | |
| 17,550 | | | | 17,599 |
| | | *Payments for Services:* | | |
| 5,000 | | British Iron and Steel Research Association | 5,000 | |
| 150 | | Andrew Carnegie Research Fund | 150 | |
| 250 | | Mond Nickel Fellowships Committee | 250 | |
| 100 | | Institute of Metals | 100 | |
| 500 | | Joint Committee for National Certificates in Metallurgy | — | |
| 6,000 | | | | 5,500 |
| 1,408 | | *Interest on Investments (gross)* | | 1,413 |
| 68 | | *Post Office Savings Bank Interest* | — | 23 |
| | | *Institute of Metals:* | | |
| 950 | | Rent, Rates, and Cleaning | 1,100 | |
| 500 | | Library | 625 | |
| 1,450 | | | | 1,725 |
| 111 | | *Sundry Receipts* | | 43 |
| | | *Publishing:* | | |
| 43,803 | | 1955 *Journal*—Revenue | 44,495 | |
| 6,762 | | Other Publishing Activities—Revenue | 8,862 | |
| 341 | | Adjustments—Amounts over-provided in previous year | — | |
| 50,906 | | | | 53,357 |
| 640 | | *Translations Service*—Sales | | 322 |
| £78,133 | | | | £79,982 |
| 3,109 | | Balance brought down | | 2,738 |
| 314 | | Surplus on Swedish Meeting | | — |
| — | | Surplus on Scunthorpe Meeting | | 382 |
| — | | Excess of Expenditure over Income for the Year | | 4,904 |
| £3,423 | | | | £8,024 |

## ACCUMULATED FUND, 31ST DECEMBER, 1955

| £ | | £ | £ | | £ |
|---|---|---|---|---|---|
| — | Joint Metallurgical Societies Meeting in Europe—Balance of account written off (see note) | 2,411 | £36,100 | Balance at 31st December, 1954 | 36,180 |
| 250 | Transfer to Reserve for Comprehensive Index | 250 | 3,330 | *Add* Excess of Income over Expenditure for the Year | — |
| 1,000 | „ „ House Fund | 1,000 | — | „ Transfer from Repairs Reserve | 3,000 |
| 500 | „ „ Reserve for Supplementing Staff Pensions | 500 | 500 | „ Transfer from Library Account | — |
| 2,000 | „ „ Reserve for Decorations and Repairs | — | | | |
| — | Excess of Expenditure over Income for the Year | 4,904 | | | |
| 36,180 | Balance carried to Balance Sheet | 30,115 | | | |
| £39,930 | | £39,180 | £39,930 | | £39,180 |

NOTE: *Joint Metallurgical Societies Meeting in Europe*

The final cost of this Meeting has not yet been ascertained. A further debit may arise in respect of amounts payable to other sponsoring bodies, while a refund of certain travelling costs is being negotiated.

## HOUSE FUND—COST OF LEASE ACCOUNT

| | |
|---|---|
| Lease at Cost, including Legal Expenses .. .. .. .. | £43,518 |
| | £43,518 |

| | To 31st Dec., 1954 | Current Year | Total |
|---|---|---|---|
| Amounts written off: | | | |
| Transfer from Accumulated Fund .. .. | £2,000 | £1,000 | £3,000 |
| Bank Deposit Interest .. .. .. .. | 118 | 3 | 121 |
| Interest on Investment .. .. .. .. | 400 | 528 | 928 |
| | | | 4,049 |
| Balance as per Balance Sheet .. .. .. | | | 39,469 |
| | | | £43,518 |

## ANDREW CARNEGIE RESEARCH FUND

### BALANCE SHEET, 31ST DECEMBER, 1955

| 1954 | | LIABILITIES | | |
|---|---|---|---|---|
| £ | £ | | £ | £ |
| 21,241 | | *Amount of Original Fund*, $100,000 .. .. .. .. .. | 21,241 | |
| 4,596 | | *Add* Amount capitalised per last Balance Sheet .. .. .. | 4,596 | |
| 25,837 | | | | 25,837 |
| | | *Sundry Creditors:* | | |
| 757 | | Grants .. .. .. .. .. .. .. .. | 1,682 | |
| 16 | | Auditors' Fees .. .. .. .. .. .. | 16 | |
| 163 | | Iron and Steel Institute—Current Account .. .. .. .. | 133 | |
| 936 | | | | 1,831 |
| | | *Reserve for Travelling Scholarships:* | | |
| 2,600 | | Balance at 31st December, 1954 .. .. .. .. .. | | 2,600 |
| | | *Accumulated Fund:* | | |
| 8,340 | | Balance per account annexed .. .. .. .. .. .. | | 7,322 |
| £37,713 | | | | £37,590 |

| 1954 | | ASSETS | | |
|---|---|---|---|---|
| £ | £ | | £ | £ |
| | | *Investments at Cost per Schedule* | | |
| 34,708 | | (Market Value at 31st December, 1955—£35,521) .. .. .. | | 36,741 |
| | | *Balances at Bank:* | | |
| | 2,376 | On Current Account .. .. .. .. .. .. .. | 188 | |
| | 10 | On Deposit Account .. .. .. .. .. .. .. | 10 | |
| | 619 | Post Office Savings Bank .. .. .. .. .. .. | 634 | |
| 3,005 | | | | 832 |
| — | | *Sundry Debtor*—Income Tax Recoverable .. .. .. .. | | 17 |
| £37,713 | | | | £37,590 |

### ACCUMULATED FUND, 31ST DECEMBER, 1955

| £ | | £ |
|---|---|---|
| 897 | Grants .. .. .. .. .. .. .. .. .. .. .. | 2,310 |
| 150 | Contribution to General Fund on account of Salaries .. .. .. .. .. | 150 |
| 16 | Audit Fee .. .. .. .. .. .. .. .. .. .. | 16 |
| 5 | Sundry Expenses .. .. .. .. .. .. .. .. | 5 |
| 8,340 | Balance carried forward .. .. .. .. .. .. .. .. | 7,322 |
| £9,408 | | £9,803 |

| 1954 | | | | |
|---|---|---|---|---|
| £ | £ | | £ | £ |
| 8,067 | | Balance at 31st December, 1953 .. .. .. .. .. | | 8,340 |
| | | Income for the year ended 31st December, 1955: | | |
| | 1,326 | Interest on Investments (gross) .. .. .. .. .. | 1,420 | |
| | 15 | Interest on Deposits .. .. .. .. .. .. .. | 16 | |
| 1,341 | | | | 1,436 |
| — | | Premiums on Conversion of Defence Bonds and Serial Funding Stock | | 27 |
| £9,408 | | | | £9,803 |

## WILLIAMS PRIZE FUND

### BALANCE SHEET, 31ST DECEMBER, 1955

| 1954 | LIABILITIES | | |
|---|---|---|---|
| £ | | £ | £ |
| 2,220 | *Capital Value* representing Market Value of £3,000 3½% Conversion Loan on 21st September, 1926, when the fund was inaugurated .. .. .. .. | 2,220 | |
| 834 | *Accumulated Fund*—Balance per Account annexed .. .. .. .. .. | 662 | |
| £3,054 | | £2,882 | |

| 1954 | | ASSETS | | |
|---|---|---|---|---|
| £ | £ | | £ | £ |
| 2,769 | | *Investments at Cost per Schedule* .. .. .. .. .. | | 2,769 |
| | | (Market Value at 31st December, 1955—£2,742) | | |
| | | *Balance at Banks:* | | |
| | 111 | On Current Account .. .. .. .. .. .. .. | 5 | |
| | 173 | Post Office Savings Bank Account .. .. .. .. .. | 107 | |
| 284 | | | | 112 |
| 1 | | *Sundry Debtor*—The Iron and Steel Institute .. .. .. .. | | 1 |
| £3,054 | | | | £2,882 |

### ACCUMULATED FUND, 31ST DECEMBER, 1955

| £ | | £ |
|---|---|---|
| 200 | Awards .. .. .. .. .. .. .. .. .. .. .. | 300 |
| 834 | Balance carried forward .. .. .. .. .. .. .. .. | 662 |
| £1,034 | | £962 |

| 1954 | | | | |
|---|---|---|---|---|
| £ | £ | | £ | £ |
| 905 | | Balance 31st December, 1954 .. .. .. .. .. | | 834 |
| | | Income for year ended 31st December, 1955: | | |
| | 121 | Interest on 3½% Conversion Loan .. .. .. .. .. | 121 | |
| | 3 | Interest on Defence Bonds .. .. .. .. .. .. | 3 | |
| | 4 | Interest on Post Office Savings Bank Account .. .. .. | 4 | |
| 128 | | | | 128 |
| 1 | | Premium on Conversion of Defence Bonds .. .. .. .. | | — |
| £1,034 | | | | £962 |

## BESSEMER MEDAL FUND

### BALANCE SHEET, 31st DECEMBER, 1955

| 1954 | LIABILITIES | | | 1954 | ASSETS | | |
|---|---|---|---|---|---|---|---|
| £ | | £ | £ | £ | | £ | £ |
| 400 | *Capital Value* representing Market Value of £400 4% Debentures of the L. & N.W. Railway | 400 | | 400 | *Investments:* £474 15*s.* 0*d. British Transport* 3% *Guaranteed Stock* 1978/88 | 400 | |
| 500 | *Grant* from the Iron and Steel Institute | 500 | | — | £500 4% Funding Stock 1960/90 (Market Value at 31st December, 1955—£810) | 500 | |
| 900 | | | 900 | | | | 900 |
| 42 | *Accumulated Fund*—Balance per account annexed | | 26 | 542 | *Sundry Debtor*—The Iron and Steel Institute | | 26 |
| £942 | | | £926 | £942 | | | £926 |

### ACCUMULATED FUND, 31st DECEMBER, 1955

| £ | | £ | £ | | | £ |
|---|---|---|---|---|---|---|
| 33 | Medal | | 33 | 61 | Balance 31st December, 1954 | 42 |
| — | Sundry Expenses | | 17 | | *Income for year ended 31st December, 1955:* | |
| 42 | Balance carried forward | | 26 | 14 | Interest on British Transport Stock | 14 |
| | | | | — | Interest on 4% Funding Stock | 20 |
| £75 | | | £76 | £75 | | 34 |
| | | | | | | £76 |

## SIR ROBERT HADFIELD MEDAL FUND

### BALANCE SHEET, 31st DECEMBER, 1955

| 1954 | LIABILITIES | | | 1954 | ASSETS | | |
|---|---|---|---|---|---|---|---|
| £ | | £ | £ | £ | | £ | £ |
| 268 | *Capital Value* representing Market Value of £267 11*s.* 2*d.* 3% Savings Bonds 1955/65 | 268 | | 268 | £267 11*s.* 2*d.* 3% *Savings Bonds* 1955/65 (Market Value at 31st December, 1955—£230) | 268 | |
| 30 | *Accumulated Fund*—Balance per Account annexed | 35 | | 30 | *Sundry Debtor*—The Iron and Steel Institute | 35 | |
| £298 | | | £303 | £298 | | | £303 |

### ACCUMULATED FUND, 31st DECEMBER, 1955

| £ | | £ | £ | | | £ |
|---|---|---|---|---|---|---|
| 3 | Medals | | 3 | 25 | Balance 31st December, 1954 | 30 |
| 30 | Balance carried forward | | 35 | | *Income for year ended 31st December, 1955:* | |
| | | | | 8 | Interest on 3% Savings Bonds | 8 |
| £33 | | | £38 | £33 | | £38 |

# THE IRON AND STEEL INSTITUTE

## SCHEDULE OF INVESTMENTS AT 31ST DECEMBER, 1955
## SHOWING NOMINAL VALUES, COST, AND PRESENT MARKET VALUES

| Nominal Value | Nature of Security | Market Value, 31st December, 1955 | Cost Value |
|---|---|---|---|
| | **GENERAL FUNDS OF THE INSTITUTE** | | |
| £ s. d. | | £ | £ |
| 2,197 7 0 | 3½% War Stock | 1,681 | 2,161 |
| 1,324 7 4 | 3½% Conversion Loan | 1,013 | 1,254 |
| 2,954 1 0 | 4% Consolidated Stock | 2,496 | 3,176 |
| 12,242 19 3 | 4% Funding Loan 1960/90 | 11,325 | 9,512 |
| 1,000 0 0 | 3% Defence Bonds (P.O. Register) | 1,000 | 1,000 |
| 2,000 0 0 | 3% Savings Bonds 1955/65 | 1,770 | 2,000 |
| 5,000 0 0 | do. 1955/65 | 4,425 | 4,972 |
| 2,000 0 0 | do. 1960/70 | 1,630 | 2,000 |
| 1,500 0 0 | do. 1965/75 | 1,193 | 1,500 |
| 4,854 2 0 | British Transport 3% Guaranteed Stock 1978/88 | 3,558 | 5,407 |
| | | £30,091 | £32,982 |
| | **LIFE COMPOSITION FUND** | | |
| 587 13 10 | 3½% Conversion Loan | 449 | 513 |
| 205 15 6 | 3½% War Stock | 158 | 212 |
| 681 13 0 | 4% Funding Loan 1960/90 | 631 | 600 |
| 196 10 1 | do. 1960/90 | 181 | 231 |
| 2,615 11 2 | British Transport 3% Guaranteed Stock 1978/88 | 1,923 | 1,893 |
| 1,250 0 0 | 3½% Defence Bonds (Conversion Issue) | 1,250 | 1,242 |
| 250 0 0 | 3½% Defence Bonds (Conversion Issue) | 250 | 248 |
| | | £4,842 | £4,939 |
| | **ANDREW CARNEGIE RESEARCH FUND** | | |
| | (Trustees: Sir William Larke, K.B.E., The Hon. R. G. Lyttelton, N. H. Rollason) | | |
| 6,897 14 11 | 3½% War Stock | 5,267 | 6,896 |
| 800 0 0 | do. | 612 | 794 |
| 2,693 12 0 | 3½% Conversion Loan | 2,060 | 2,007 |
| 3,922 14 10 | 4% Conversion Stock 1957/8 | 3,863 | 3,998 |
| 1,793 15 0 | British Electricity 3% Guaranteed Stock 1968/73 | 1,553 | 1,762 |
| 4,166 18 7 | 4% Funding Stock 1960/90 | 3,855 | 4,676 |
| 500 0 0 | 2½% Defence Bonds (P.O. Register) | 500 | 500 |
| 1,250 0 0 | 3% Defence Bonds (P.O. Register) | 1,250 | 1,250 |
| 750 0 0 | 3½% Defence Bonds (Conversion Issue) | 750 | 745 |
| 17,812 10 3 | British Transport 3% Guaranteed Stock 1978/88 | 13,092 | 10,863 |
| 1,000 0 0 | 3% Savings Bonds 1955/65 | 885 | 1,000 |
| 2,250 0 0 | do. 1960/70 | 1,834 | 2,250 |
| | | £35,521 | £36,741 |
| | **WILLIAMS PRIZE FUND** | | |
| | (Trustees: Sir William Larke, K.B.E., The Hon. R. G. Lyttelton, N. H. Rollason) | | |
| 3,452 15 7 | 3½% Conversion Loan | 2,642 | 2,670 |
| 100 0 0 | 3½% Defence Bonds (P.O. Register) | 100 | 99 |
| | | £2,742 | £2,769 |
| | **SIR ROBERT HADFIELD MEDAL FUND** | | |
| 267 11 2 | 3% Savings Bonds 1955/65 | £230 | £268 |
| | **BESSEMER MEDAL FUND** | | |
| | (Trustees: Desmond Lysaght, The Hon. R. G. Lyttelton, N. H. Rollason) | | |
| 474 15 0 | British Transport 3% Guaranteed Stock 1978/88 | £349 | — |
| 500 0 0 | 4% Funding Stock 1960/90 | 461 | 500 |
| | | £810 | £500 |
| | **HOUSE FUND** | | |
| 10,000 0 0 | 4% Funding Stock 1960/90 | £9,250 | £10,131 |
| 3,200 0 0 | 4% Funding Stock 1960/90 | 2,960 | 3,251 |
| | | £12,210 | £13,382 |

(*Signed*) W. BARR,
*Hon. Treasurer*

(*Signed*) K. HEADLAM-MORLEY,
*Secretary*

We have examined the foregoing Balance Sheets and Income and Expenditure Accounts with the Books and Vouchers of the Institute and certify them to be correct. We have also verified the balances at the Bankers and the Securities for the Investments shown above.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET, E.C.2
25*th March*, 1956

(*Signed*) W. B. KEEN & Co.,
*Chartered Accountants*

# *PROGRAMME FOR SPECIAL MEETING IN FRANCE, 1956*

The Council have accepted an invitation from the Chambre Syndicale de la Sidérurgie Française (the President at the time when the invitation was issued was the late Monsieur P. Ricard) and the Société Française de Métallurgie (President Baron F. Walckenaer) to hold a Special Meeting of The Iron and Steel Institute in France from **Tuesday, 5th June, to Thursday, 14th June, 1956.**

The Chambre Syndicale de la Sidérurgie Française have undertaken the responsibility for the arrangements in France in collaboration with Dr. E. Dupuy (Honorary General Secretary and Past-President of the Société Française de Métallurgie) and Monsieur P. Gouge (Société Métallurgique de Normandie).

The Meeting is divided into two Sections—SECTION I from 5th to 11th June in Paris; and SECTION II from 11th June: three *alternative* excursions to the iron and steelmaking areas.

Members and Ladies who register for the Meeting will be able to take part in Section I of the Meeting, and also in *one* of the excursions to the iron and steelmaking areas.

The programme is as follows:

## SECTION I—PARIS

### Monday, 4th June

Evening: Members and Ladies arrive in Paris.

### Tuesday, 5th June

Members and Ladies:

11.30 A.M.: Reception at Hôtel de Ville, Paris.

Midday: *Excursion* 1 by boat on the River Seine. Luncheon on board.

Afternoon: Plenary Opening Session at the Sorbonne.

Evening: Reception at the Louvre. (Dress: Lounge suits.)

### Wednesday, 6th June

Morning: Members—Technical Sessions (*see below*).
Ladies—Free.

Afternoon: Members may take part in *one* of the following excursions to Works in the neighbourhood of Paris:

*Excursion* 2—Régie Nationale des Usines Renault: Billancourt Works (motor vehicle assembly; machine shops; foundry).

*Excursion* 3—Société Nationale d'Étude et de Construction de Moteurs d'Aviation: Kellermann Works (manufacture of aircraft gas-turbine engines).

*Excursion* 4—Union Technique de l'Automobile et du Cycle et Centre Technique des Industries de la Fonderie: Sèvres. (Central Research Laboratories for the foundry industry.)

*Excursion* 5—Institut de Recherches de la Sidérurgie: St. Germain-en-Laye. (Central Research Organization of the French iron and steel industry.)

*Excursion* 6—Société Industrielle de Mécanique et de Carrosserie Automobile (SIMCA): Poissy Works (motor-car manufacture).

*Excursion* 7—Centre d'Etudes Nucléaires du Commissariat à l'Énergie Atomique: Saclay. (Research Centre of the Atomic Energy Authority of France.)

*Excursion* 8—Centrale Arrighi de l'Électricité de France. (Electricity Distribution Centre.)

Ladies—Reception and tea at the house of Mme. Charles Schneider.

Evening: Members and Ladies—Visit to the Opera. (Dress: Evening dress or dinner jackets.)

### Thursday, 7th June

Members and Ladies may take part in *either*:

*Excursion* 9: All day (Members and Ladies)—Visit by special train to the Works of the Société Française de Métallurgie at Mondeville, near Caen (blast-furnaces, coke-ovens, basic Bessemer and open-hearth steel plants; bar and wire rod mills; wire-drawing). Luncheon and high tea by invitation of the Company. Excursion to the Normandy Beaches and Bayeux.

*or*

*Excursion* 10: All day (Members)—Morning: Visit to laboratories of Institut de Recherches de la Sidérurgie, St. Germain-en-Laye (Repeat of *Excursion* 5).

Midday: Luncheon at the Pavillon Henri IV at St. Germain, by invitation of the Chambre Syndicale de la Sidérurgie Française (with Ladies—see *Excursion* 11).

Afternoon: Visit to Régie Nationale des Usines Renault, Flin Works (motor-car manufacturers).

*Excursion* 11 (Ladies)

Midday: Luncheon at the Pavillon Henri IV at St. Germain-en-Laye (with Members—see *Excursion* 10).

Afternoon: Visit to Malmaison.

Evening: Members and Ladies—Free.

### Friday, 8th June

Morning: Members—Technical Sessions (*see below*).
Ladies—Free.

Afternoon: Members may take part in *one* of the following excursions to Works in the neighbourhood of Paris:

*Excursion* 12 — Régie Nationale des Usines Renault: Billancourt Works. (Repeat of *Excursion* 2.)

*Excursion* 13—Société Industrielle de Mécanique et de Carrosserie Automobile (SIMCA): Nanterre Works (motor-car manufacture).

*Excursion* 14—Société des Tréfileries et Laminoirs du Havre: St. Maurice Cable Works (manufacture of rubber-insulated and paper-insulated electric cables).

*Excursion* 15—Institut de Recherches de la Sidérurgie: St. Germain-en-Laye. (Repeat of *Excursion* 5 and part of *Excursion* 10.)

*Excursion* 16—Station d'Essais de la Société Nationale des Chemins de Fer Français: Vitry. (Central Testing Station of the French Railways.)

*Excursion* 17—Centre National de la Recherche

Scientifique: Vitry Laboratory. (Metallurgical and metallographic research laboratories.)
*Excursion* 18—Centre National de Calculateurs Électroniques. (Electronic computers.)
Ladies: *Excursion* 19—Tea and Fashion Parade at the Eiffel Tower.
Evening: Members and Ladies—Banquet, Illuminations, and Dance at the Palace of Versailles. (Evening dress and decorations.)

**Saturday, 9th June**

All Day: Members and Ladies may take part in *one* of the following:
*Excursion* 20—Chantilly (Château, etc.).
*Excursion* 21—Chartres (Cathedral, etc.).
*Excursion* 22—Fontainebleau (Château, etc.).
Evening: Members and Ladies—Free.

**Sunday, 10th June**

All Day: *Excursion* 23—Members and Ladies (except those taking part in Excursion B to Central France) will be able to visit Chantilly Race-Course to see the French "Derby." There will be no other organized programme on this day.
Afternoon: Members and Ladies taking part in Excursion B to Central France will leave Paris by train for Chalon-sur-Saône.
Evening: Members and Ladies—Free.

*End of Meeting in Paris*

## SECTION II—EXCURSIONS TO IRON AND STEELMAKING AREAS

### Excursion A: Eastern France

**Monday, 11th June**

Morning: Members and Ladies leave Paris by train for Metz.
Midday: Members and Ladies—Official Reception and Lunch at Metz by invitation of the Chambre Syndicale de la Sidérurgie de la Moselle.
Afternoon: *Excursion* A1 (Members)—Visit to the Rombas Works of Union Sidérurgique Lorraine (SIDELOR). (Blast-furnaces; basic Bessemer and open-hearth steelplants; rolling mills for sections, rails, and sheet piling.)
*Excursion* A2 (Ladies)—Visit to Verdun and Douaumont.
Evening: Members and Ladies—Free in Metz.

**Tuesday, 12th June**

Morning: *Excursion* A3 (Members)—Visit to Société Lorraine de Laminage Continu (SOLLAC). (Basic Bessemer and open-hearth steelworks; hot and cold wide continuous strip mills; electrolytic tinning.)
*Excursion* A4 (Ladies)—Sightseeing tour of Metz.
Midday: *Excursion* A5 (Members and Ladies)—Luncheon at SOLLAC by invitation of the Company.
Afternoon: *Excursion* A5 (Members and Ladies)—Visits to places of interest near Thionville.
Evening: Members and Ladies—Dinner and Dance in Metz.

**Wednesday, 13th June**

Morning: Members may take part in *one* of the following excursions to Works at Longwy:
*Excursion* A6—Soc. Anon. des Hauts Fourneaux de la Chiers (to see a modern wire rod mill).
*Excursion* A7—Soc. Anon. des Laminoirs, Hauts Fourneaux, Forges, Fonderies et Usines de la Providence: Rehon Works (to see a modern hoop mill).
*Excursion* A8—Société Lorraine-Escaut, Mont-St.-Martin Works (to see a modern four-high plate mill).
Midday: Members and Ladies—Lunch at Longwy by invitation of Union des Mines et de la Métallurgie de Longwy.
Afternoon: *Excursion* A9 (Members)—Visit to central power station and tonnage oxygen plant near Longwy.
All Day: *Excursion* A10 (Ladies)—Visits to Longuyon (lunch), Orval (Abbey), Avioth and Marville, joining Members for tea at Longwy.
Evening: Members and Ladies—Dinner in Metz: board special sleeping-car train for Calais.

### Excursion B: Central France

**Sunday, 10th June**

Evening: Members and Ladies—Leave Paris by train for Chalon-sur-Saône.

**Monday, 11th June**

All Day: *Excursion* B1 (Members)—Visit to the Works of Société des Forges et Ateliers du Creusot (open-hearth and electric steelplants; mills for billets and plates; heavy forge; heavy engineering works; laboratories). Lunch by invitation of the Company.
*Excursion* B2 (Ladies)—Visit to Beaune and the winegrowing district of Burgundy. Lunch at Pommard by invitation of the Société Française de Métallurgie.
Evening: Members and Ladies—Travel by train to Lyons.

**Tuesday, 12th June**

All Day: *Excursion* B3 (Members)—Visit to the Works of Cie. des Ateliers et Forges de la Loire at Firminy (open-hearth and electric steel plant; bar and wire rod mills; forge; stamping shop) and at Unieux (steelworks; continuous casting plant) in the morning. Lunch by invitation of the Company. In the afternoon, visit to the St. Chamond Works of the same company (foundry; forge).
*Excursion* B4 (Ladies)—Sightseeing in Lyons and excursion (with lunch at Nantua) to Bourg (Church of Brou), Nantua (lake), and Pérouges (restored mediaeval village); tea with Members at St. Chamond.
Evening: Members and Ladies—Dinner at St. Étienne. Leave by sleeping-car train for Paris.

*End of Meeting*

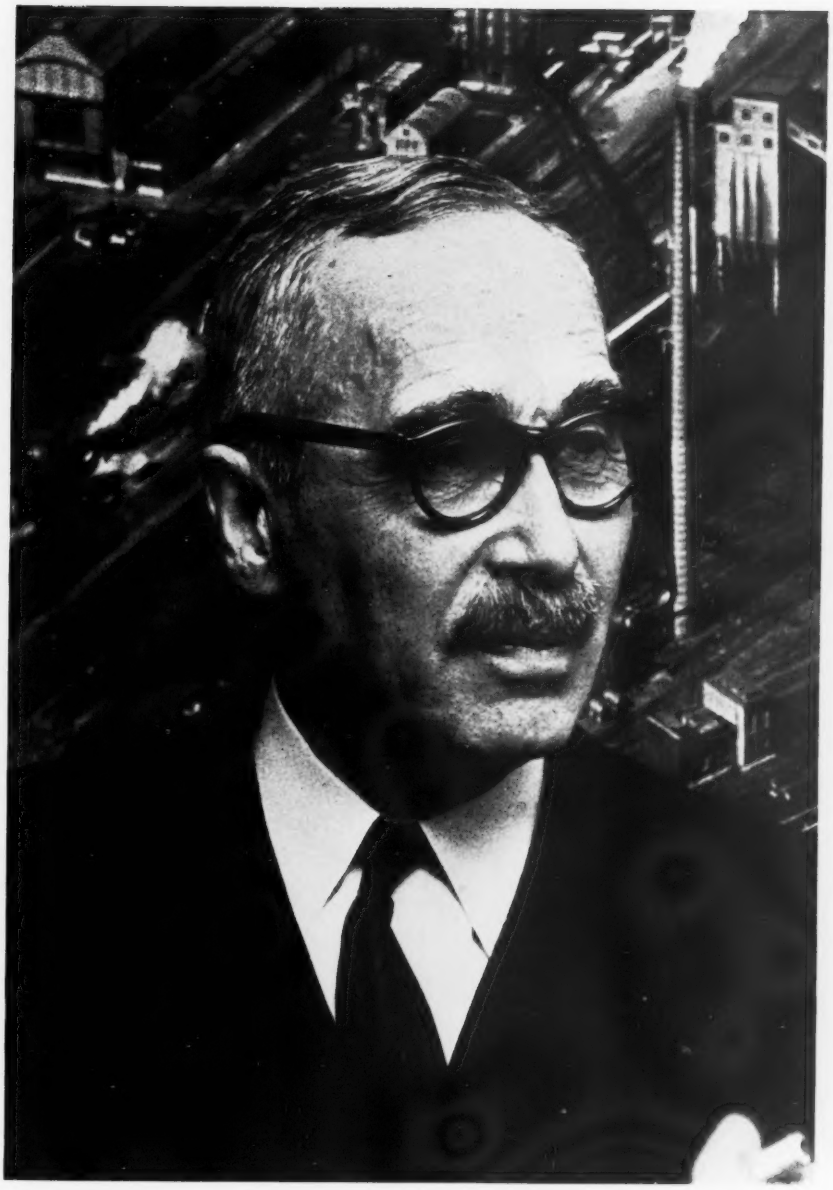
## TECHNICAL SESSIONS IN PARIS

**Wednesday, 6th June**

Two technical sessions will be held simultaneously at the Chambre Syndicale de la Sidérurgie Française from 10.0 A.M. to 12 NOON for the presentation and discussion of the following papers:

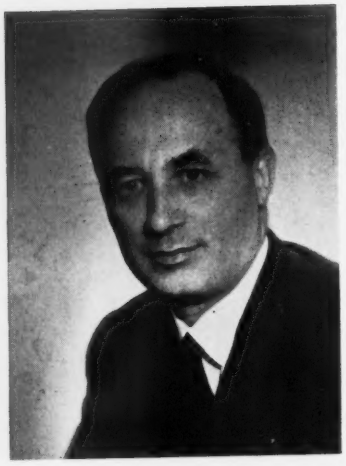
*Session A*

10.0 to 11.0 A.M. "Instrumentation in Steelworks," by *G. Husson* and *J. Leroy*, IRSID (May, 1956).
11.0 A.M. to 12 NOON: "Studies on a 10-cwt Arc Furnace," by *W. H. Glaisher*, *M. Preston*, and *J. Ravenscroft*, BISRA (May, 56).
and "Some Factors Affecting Electrode Consumption

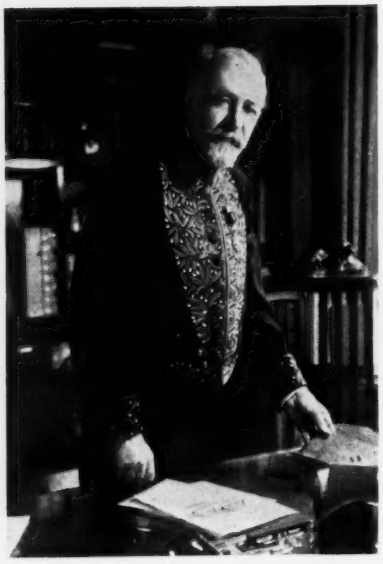


**Baron Walckenaer**

[*To face p.* 16

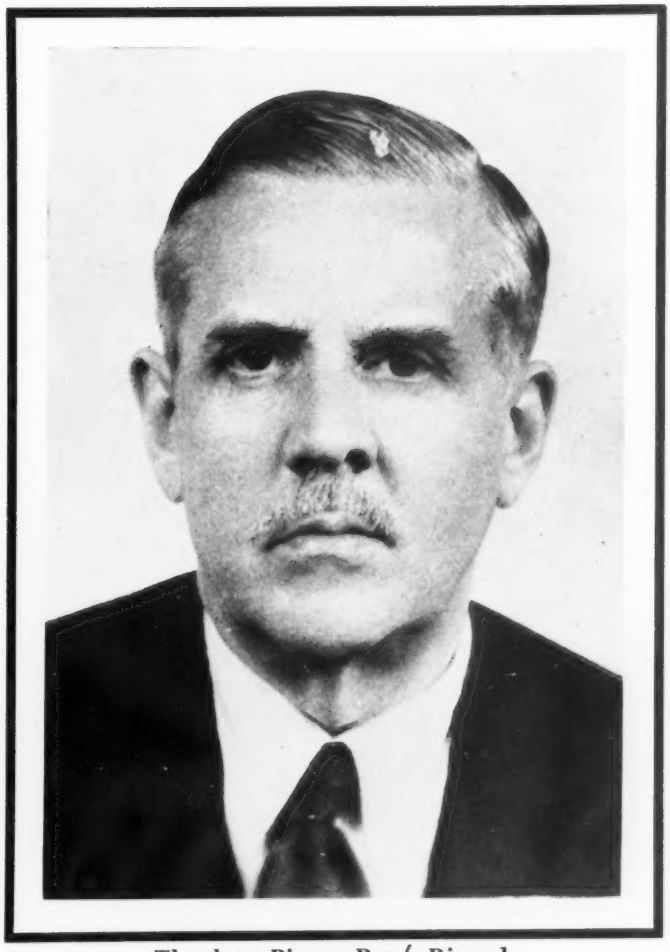


Henri Malcor



Albert Portevin

Eugène Dupuy



**The late Pierre René Ricard**

## Monsieur Jean Raty

Monsieur Jean Raty accepted, in April, 1956, an invitation to become Président de la Chambre Syndicate de la Sidérurgie Française as successor to the late Monsieur Pierre Ricard.

A photograph and biographical notes of Monsieur Raty will be published in the June issue of the Journal.

*To face p.* 17]

in the Electric-Arc Furnace," by *D. H. Houseman*, Sheffield University (May, 1956).
(Joint Discussion)

*Session B*

10.0 to 11.0 A.M. "The Effects of Gravity on the Solidification of Steel," by *B. Gray*, English Steel Corporation Ltd. (April, 1956).

11.0 A.M. to 12 NOON: "Applications of the Electron Probe Microanalyser," by *J. Philibert* and *C. Crussard*, IRSID (May, 1956).

**Friday, 8th June**

Two technical sessions will be held simultaneously at the Chambre Syndicale de la Sidérurgie Française from 10.0 A.M. to 12 NOON for the presentation and discussion of the following papers:

*Session C*

10.0 to 11.0 A.M. "Studies on a Model of Aerodynamics of a Maerz-type Open-Hearth Furnace," by *G. Husson* (IRSID), *G. Cohen de Lara* and *R. Durand*, Laboratoire Dauphinois d'Hydraulique (June, 1956).

11.0 A.M. to 12 NOON: "Desulphurization of Liquid Pig Iron by Blowing with Limestone Powder," by *B. Trentini*, *L. Wahl* and *M. Allard*, IRSID (June, 1956).

*Session D*

10.0 to 11.0 A.M. "Sulphur Partition between Gas, Slag, and Metal Phases under Iron and Steelmaking Conditions," by *E. T. Turkdogan*, BISRA (February, 1955).

11.0 A.M. to 12 NOON: "A Study of Impact Tests and the Mechanism of Brittle Fracture," by *C. Crussard*, *R. Borione*, *J. Plateau*, *Y. Morillon* and *F. Maratray*, IRSID (June, 1956).
and "Some Effects of Heat-treatment and Microstructure on the Transition Temperature of a 0·24% Carbon Steel," by *G. Burns* and *C. Judge*, Department of Aeronautical and Engineering Research, Admiralty (March, 1956).
(Joint Discussion)

The first discussions at both sessions on each day will close at 10.55 A.M. to enable Members to be present at the beginning of either of the second discussions. These will start at 11.0 A.M. precisely.

The dates given after each paper denote the monthly *Journal* in which each paper is to be published; where papers are scheduled for publication in the June, 1956 *Journal*, preprints will be issued to all those attending the Meeting.

A paper on "*The French Iron and Steel Industry*," by M. Allard, IRSID, which has been specially prepared for the Meeting, is published in this issue (pp. 19–21), but will not be formally presented or discussed.

The lecture on "*Sir Henry Bessemer*" by G. Delbart, IRSID, will be published in the *Journal* for June, 1956; preprints will not be issued.

## BIOGRAPHIES

**François, Baron Walckenaer,** was born in 1889, the son of Charles Walckenaer, Vice-President of the Conseil Général des Mines. He is the great-great-grandson of Charles Athanase Walckenaer (1771–1852), a member of the first class to graduate from the École Polytechnique, Permanent Secretary of the Académie des Inscriptions et Belles-Lettres, and a founder-member of the Société de Géographie.

Baron Walckenaer entered the École Polytechnique in 1908 and on graduation in 1912 joined the Corps des Mines. He joined the Army in 1914 and served with distinction in the artillery and the air force, being created a Chevalier de la Légion d'Honneur (1916) and awarded the Croix de Guerre, 1914–1918. One brother, Charles, was killed in 1914; the other, Bernard, lost his life in the second world war, in 1940.

From 1919 to 1920 Baron Walckenaer served with the Service Ordinaire des Mines (Circonscription d'Arras). In 1920 he joined the Établissments Schneider, and was Director of the Le Creusot works from 1925 to 1935. He is now technical consultant to the company.

Baron Walckenaer has taken an active part in the work of companies in the iron and steel industry of France and in the activities of metallurgical societies. He became President of the Société Métallurgique de Normandie in 1942, President of the Société Métallurgique de Knutange in 1953, and Vice-President of the Chambre Syndicale de la Grosse Forge in 1945. He is President of the Société Française de Métallurgie for 1956. He was promoted to Officier de la Légion d'Honneur in 1950.

Baron Walckenaer was married in 1919. His wife was Mademoiselle Marie Chabert. They have five children, all of whom are married. There are sixteen grandchildren.

**Albert Portevin** was born in Paris in 1880. He entered the École Centrale in 1899 and graduated first in Chemistry after exceptionally brilliant studies.

He was for a time with the Crédit Lyonnais, studying finance, and later with the Société Métallurgique de la Bonneville, and then joined the Dion-Bouton Factories as Chief Chemist.

This marked the beginning of his scientific and industrial work, and from this time date the first of the some 500 papers that he has devoted to metallurgy in general and to iron-smelting in particular. Many of these papers have promulgated in France important work by foreign scientists; others have revised previous knowledge on the structure of metallurgical products and their relation to physical, chemical, and mechanical properties; others constitute a study of thermal treatments and, in particular, the tempering of steels and the relation of the properties of metals to the processes used in the industry: tempering, forging, welding, and smelting.

These contributions and the work they represent have brought Albert Portevin numerous awards, in the Ingénieurs Civils, the Société d'Encouragement pour l'Industrie Nationale, the Association des Méthodes d'Essais, and the Association Technique de Fonderie. His merit was soon recognized abroad and he has been honoured by many foreign societies and by International Congresses.

In 1909 he was awarded the Carnegie Medal of The Iron and Steel Institute, in 1935 the Institute's Bessemer Gold Medal, and then in 1950 the Platinum Medal of The Institute of Metals, becoming the only scientist to receive all three of these awards. Amongst other honours, he has been awarded the Osmond Medal of the Société Française de Métallurgie and the Lavoisier Medal of the Société d'Encouragement pour l'Industrie Nationale, the Seaman Medal of the American Foundrymen's Society, the Transenster Medal of the Association des Ingénieurs Sortis de l'Ecole de Liège, the Crismer-Peny Prize of the Société Chimique de Belgique, the Grand Medal of the Société de Chimie Industrielle, and the Prix d'Honneur of the International Committee of the Association de Fonderie.

Many foreign Universities have welcomed Albert Portevin as a Doctor *honoris causa*, namely, those of Liège, Brussels, Louvain, Genoa, Cracow, Zurich,

Quebec, and Aachen, as well as the École des Mines, Pribram.

He has been elected a Foreign Corresponding Member of the Royal Society and of the Academies of Barcelona, Madrid, Prague, Stockholm, and Warsaw, an Associate Member of the Institute of Egypt and the National Academy of Science of the U.S.A., and an Honorary Member of the Academy of Ferrara, the American Institute of Mining and Metallurgical Engineers, the Institute of Metals, and The Iron and Steel Institute.

Professor Portevin is a Grand Officer of the Legion of Honour and the Order of Alphonso X (Spain). He is also a Commander of the Order of Leopold (Belgium), the Order of the Oaken Crown (Luxembourg), the Order of the Polar Star (Sweden), an Officer of the White Lion (Czechoslovakia), and an Officer of the Crown (Italy); he holds the Gold Cross of Merit (Poland).

The variety of Portevin's scientific and industrial activities is indicated by the societies of which he has been or is President: the Société Chimique de France, the Société Française de Minéralogie, the Société Française de Métallurgie, the Association Technique de Fonderie, the Société des Ingénieurs de l'Automobile, the Société Française de Physique, and the Institut de Soudure Autogène, the Association Française pour l'Essai des Matériaux, and also the Collégé International pour l'Étude Scientifique des Techniques de Production Mécanique. He was also the Founder Vice-President of the Institut International de la Soudure, Vice-President of the Société d'Encouragement pour l'Industrie Nationale, and the Société Française des Mécaniciens, and is President General of the Commission Internationale pour l'Essai des Fontes.

In the field of teaching too Albert Portevin has achieved great success. A Professor at the École Supérieure de Fonderie, he later became its Director and, as a Professor at the École Supérieure de Soudure Autogène, he became President of the Conseil de Perfectionnement. For more than 40 years he has been connected with the teaching staff of the École Centrale which he joined in 1910 to create the Laboratory of Microscopical Metallography. At the École Centrale he became President of the Council and later President of the Council of Administration.

In yet another sphere, Albert Portevin is Engineering and Metallurgical Consultant to many Metallurgical and Chemical Publications and is Scientific Adviser to IRSID, and Technical Director and President of the Editorial Committee of the *Revue de Métallurgie*. He is on the Science Committee of the U.N.E.S.C.O. National Commission (France) in the capacity of Permanent Consultant. During the late war he served as Scientific Assistant and Technical Adviser at the Ministry of Armaments and at the Air Ministry.

The work of Albert Portevin has continuously related the work being carried out in the Schools and Universities to the many problems encountered in industry and both have benefited greatly from this liaison.

The eminent career of this great scientist opened to him in 1942 the doors of the Académie des Sciences to which he was elected by an unanimous vote.

Promoted Commander of the Legion of Honour in 1948 for services to national education, Professor Portevin was later elevated to the dignity of Grand Officer by the Minister of Industry and Commerce.

**Henri Malcor** was born in 1906 and educated at the École Polytechnique and the École des Mines in Paris. He served with the Corps des Mines until 1931, when he joined the Compagnie des Aciéries de la Marine, his present company. He was engineer first at the iron and steelworks at Homecourt in Lorraine and then at the steelworks at St. Chamond and Assailly in Central France. He next took over the management of the iron-ore mines at Anderny Chevillon, and then became managing director of the Compagnie des Aciéries de la Marine. Since its inception in 1954, Monsieur Malcor has been President of the Compagnie des Ateliers et Forges de la Loire.

Monsieur Malcor has been President, since their foundation, of the Centre de Documentation Sidérurgique (C.D.S.), the Institut de Recherches de la Sidérurgie (IRSID), and the International Low-Shaft Furnace Committee. He is the author of numerous technical papers in both French and British journals.

The late **Pierre René Ricard** was born at Cannes in 1899. He was educated at the École Polytechnique and spent 12 years with the Corps des Mines. In 1938 he became director and general manager of an important iron foundry. In 1946 he was made Executive Vice-President of the Syndicat Général des Fondeurs de France, and in that post was responsible for creating an industrial research centre that has served as a model for many later organizations.

In 1952 Monsieur Ricard was appointed First Vice-President of the Chambre Syndicale de la Sidérurgie Française, and was President from 1953 until his death on 4th April, 1956. He represented steel producers on the Advisory Committee to the High Authority of the European Coal and Steel Community. He was also Vice-President of the Conseil National du Patronat Française, Honorary President of the Syndicat Général des Fondeurs de France, Honorary President and member of council of the Centre Technique des Industries de la Fonderie, and a director of a number of companies. Monsieur Ricard was Commandeur de la Légion d'Honneur, Commandeur de l'Ordre de Léopold, and Commandeur de l'Ordre de l'Économie Nationale.

# The French Iron and Steel Industry

*By Marc Allard*

THE FRENCH IRON AND STEEL INDUSTRY is based on the ore of eastern France, with works in the Nancy and Longwy areas, and especially in the Moselle basin, around Metz. It benefits in this region from the important deposits of coking coal in Lorraine, which have been exploited only comparatively recently. In the west of France the Mondeville works is also situated on an orefield, near Caen. In the north, steelworks have been set up in the coalmining region ; they receive their ore supplies from the east, from Normandy, and by boat from Africa. In central France steelmaking is carried out in the coalmining areas, in the region of Saint-Etienne and Le Creusot. With the advent of hydro-electric power, important steelworks have been developed especially at Ugine in the Alps. The industry in central and southern France is concerned in particular with special steels. Finally there are a number of smaller works, spread over other parts of the country, and these have for the most part more specialized products.

The overall production of steel in France for 1955 was 12,600,000 metric tons, derived regionally as follows :

| | |
|---|---|
| Eastern France | 66·2% |
| Northern France | 22·2% |
| Western France | 4·3% |
| Central and Southern France | 7·3% |

Of this 61·7% was basic Bessemer steel, 31% open-hearth steel, and 7·3% electric steel.

This analysis shows the nature of the French iron and steel industry, which is essentially based on the treatment of basic Bessemer iron (typical analysis C 3·7%, P 1·75%, Si 0·4%, Mn 0·6%, S 0·050%), according to the nature of the ore from which it was derived, since, owing to a shortage of scrap, the production of open-hearth steel can make little progress. Unfortunately the supplies of coke for French blast-furnaces are inadequate.

Since it is not possible in so short a paper to trace the whole history of the French iron and steel industry, this paper will be confined to a brief survey of its evolution, of the conditions of working, and of the lines of development.

As it had been hampered financially by the price policy obtaining in the country before the second world war, the French industry was unable to develop its plants adequately, particularly in the sphere of flat-rolled products. Moreover, public opinion—and the press which forms that opinion—was ill-informed about the importance to a country of a prosperous steel industry, a basic industry which influences the fortunes of every other industry. Without the support of public opinion and of public bodies, the question of financing new plant was not easily resolved.

The unhappy fact must also be borne in mind that the French steel industry was for four years deep in a state of slumber, shot through with ghastly nightmares. It awakened at the end of the war with neglected equipment, works partly or totally destroyed, and scattered personnel who had lost their former skill. During this time, the war effort of the fighting powers had given a marked stimulus to their production and their technical progress.

Starting up the works in late 1944 and 1945 was further handicapped by serious supply difficulties, due in particular to the destruction of ways and means of transport.

However, the country's great and pressing demand for steel, since every reconstruction project was dependent on iron and steel production, put the industry at the head of the list of national priorities. In the feverish efforts to put the steelworks back into production, staffs had to be reorganized and retrained so as to overhaul and put back into operation everything that was still capable of being used, until such time as new plant could be made and installed. At the same time as it began to go into production for the sake of the country, the industry was outlining its plans for the future. This time the goodwill of the public authorities had been obtained.

A programme of modernization and re-equipment was already in hand in 1945–1946, but it was tempered with discretion, in view of the difficulties of the times. A moderate expansion of the pre-war productive capacity was envisaged, as well as the provision of new rolling-mill installations, especially in the field of flat products. This programme, which was evolved and supported by both private enterprise and public authorities, implied, by reason of its proposed rationalization, certain individual sacrifices which could not

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Monsieur Allard is Director-General of the Institut de Recherches de la Sidérurgie (IRSID).

help causing some resentment. To achieve the necessary financial backing, it was also necessary that there should be some concentration of interests and regrouping and division of existing works. In particular an attempt had to be made to overcome the disadvantages of the relatively small size of most French works.

Although there may have been some errors of detail and foreseeable delays that were not always heeded, on the whole these co-ordinated efforts have borne fruit. Two important companies, the Forges de Denain Anzin and the Aciéries du Nord et de l'Est, pooled their resources in order to provide in the north a plant for hot and cold wide-strip rolling, under the title of ' USINOR.' Shortly afterwards several companies in the east contributed jointly to the creation of the Société Lorraine de Laminage Continu (SOLLAC) for continuous sheet rolling using more powerful equipment. This programme was completed with other important plants, especially a continuous strip mill at the Société de la Providence at Rehon-Longwy and a heavy plate mill at Longwy (Société Lorraine-Escaut). As a result of this programme, French production of flat-rolled products is now two and a half times the pre-war figure. In 1955 the production of flat-rolled products was 3½ million metric tons, compared with 1½ million in 1929, which was then considered to be a large output. The modernization of rod, bar, and section mills was not neglected, and France now possesses a rolling capacity capable of processing the greatly increased production of steel.

At the same time, the erection of two important electric power stations run on blast-furnace gas, one at Richemont in the Moselle basin and the other at Herserange in the Longwy basin, has largely freed the smaller plants from the disadvantages of smaller individual power stations, which were always at the mercy of any mishap at the blast-furnaces. These new communal power stations receive the gas from a number of neighbouring works and redistribute to them the electric power produced. Thus a single powerful and well supplied ' heart ' beats for each member of the rationally organized community. This co-operative system has been extended to oxygen-producing centres.

Another very important co-operative creation of the French iron and steel industry must not be ignored, namely the Institut de Recherches de la Sidérurgie (IRSID). This was founded in 1946, and its principal laboratories at Saint-Germain-en-Laye will soon be supplemented by an important pilot plant now in course of erection near Metz. In addition to carrying out fundamental research, IRSID has successfully conducted important practical researches at industrial level, in which works have joined with the specialized services of IRSID. This co-operative work has proved very fruitful.

The French steelworks do not have enough scrap at their disposal to develop the open-hearth process. Metallic iron, even in the form of remelted scrap, is indeed a treasure, but that treasure must be created. This is done by means of blast-furnaces, which implies that French coke consumption is relatively high. In 1955 French steel production was 12,600,000 metric tons, compared with 20,100,000 in the United Kingdom, i.e. only 62·5% of British production. Nevertheless, coke consumption was about the same in both countries. It is true, however, that the U.K. used a great deal of imported rich ores in 1955 for making a little more than 12,500,000 metric tons of pig iron, compared with 11,000,000 in France.

So far as ore is concerned, France has important reserves in the east (the minette ores of Lorraine) and in the west. The latter deposit, which is capable of extensive exploitation in the future, at present supplies only the Mondeville works, whilst the Lorraine ore is used by the important steelworks in the east and north of France and in Belgium. With a few exceptions, underground mining is used ; the modernization began just before the war has been greatly extended, and the individual output per man has risen from an average of about 5 tons per shift to 7 tons per shift, with as much as 13 tons in some mines. It is hoped that the average will soon reach 9 tons. Thanks to these improvements the supply of ore to French works will not be a cause for anxiety for many years to come. Mechanization has led to the ore being mined in large pieces ; this has required the installation of extensive crushing equipment, which gives rise to large amounts of fines. On the other hand, while the minette ores have a relatively low iron content (32–33%), those exploited up to the present have a calcareous gangue, which means that it is easy to make up burdens that are self-fluxing and strongly basic. The policy is now to replace the calcareous ores by a more determined exploitation of the siliceous ore beds. This development in iron-ore mining is parallelled, as will be seen later, by a development in blast-furnace techniques. It should be added that France, whose iron-ore production in 1955 was over 50 million metric tons (three times that of the U.K.), supplies not only her own blast-furnaces, but also those of her neighbours.

The situation with regard to supplies of coke and coking coal is less favourable than that of ore, since France has only limited quantities of coal that is suitable for coking. As a result of research carried out largely since the war, 70% of the Lorraine coal can now be used for the production of metallurgical coke. One furnace has even been run entirely on Lorraine and Saar coke, an experiment which proved very satisfactory. It is possible to envisage in the future that France will be far less dependent than in the past on foreign supplies. New coke-oven plants are being built and the older ones are being adapted to suit this new trend. The use of processes such as the Marienau (dry charging) or selective crushing (Sovaco) is becoming more widespread.

New equipments and techniques for ironmaking, and consequently for steelmaking, had to be adapted to suit the new conditions resulting from the modifications just described in the qualities of ore and coke available. After the first world war French blast-furnaces were medium-sized ; it was accepted that the minette ores were not suitable for large furnaces. The furnaces were not driven hard and production peaks were obtained by charging scrap. The charge consisted of ore dug by hand in small pieces, without large lumps and producing a small amount of fines.

The abundance of relatively rich calcareous ores permitted a high basicity index and thus desulphurization was good. Manganese ore was also added to the charge and high-quality coke was demanded. Nowadays the need for metal requires larger furnaces that are blown harder, which means that if care is not taken there is an increase in flue dust ; the coke used is less resistant and the burdens are poorer, while the addition of manganese ore to the charge has been discontinued or greatly reduced.

All these factors, together with several others, can be summarized in the following conditions :

(i) Coke consumption per ton of iron must be reduced
(ii) Blast-furnaces must be designed to operate on coke of inferior quality
(iii) Blast-furnace productivity must be increased
(iv) The basicity of burdens must be reduced.

Yet at the same time the steelworks must still receive good-quality iron—i.e. desulphurized and low in silicon.

These various requirements show automatically the course the programme of research, operation, and construction the French steel industry has been obliged to follow; in fact, the preparation and blending in terms of composition and size of burdens were tested in conditions very similar to those at Appleby-Frodingham.

A first step in this programme was to construct plants large enough to sinter all the crushing fines and flue dust, leaving only pieces of ore of about 2–2½ in. in the untreated state for charging to the blast-furnace. It may be possible to go still further at a later stage.

At the same time a programme of systematic study of French ores and the possibilities of enriching them was begun, and an industrial plant is already envisaged to deal with a system that appears to be suitable.

Finally, processes for correcting iron that is too high in silicon or phosphorus were investigated. As a result of studies on the section of a converter it is now possible to blow iron high in silicon in 50–55-ton converters without danger. Pre-refining with oxygen is already in industrial use, and a very effective and economical method of desulphurization has just been evolved.

All these achievements are economically sound. They can moreover be adapted to the production of iron in large blast-furnaces such as those now projected as well as to electric furnaces; the use of the latter has not been rejected as a possibility for the future, especially if, as seems likely, nuclear energy is developed to provide a reasonably priced source of electric power *in situ* (i.e. on the ore deposits), so as to avoid the need to transport heavy raw materials.

But this iron has to be made into steel. Owing to the nature of the ores, they contain phosphorus to an extent which makes them suitable for the basic Bessemer process, or the Thomas process, as it is known in France. That is why the adaptation of the Bessemer process by Sidney Gilchrist Thomas to enable it to refine basic pig iron has found a home in France. Thus, despite the installation of several open-hearth steelworks, themselves partly supplied with high-phosphorus iron, the linchpin of French steel-making remains the basic Bessemer steelworks, and it is in this sphere that the problems of production, quality, and standard of product must be studied and solved. Although proportionally basic Bessemer steel has decreased in France from 69% in 1929 to 60% in 1955, to the benefit of open-hearth steel, the tonnage produced has increased by 15% over that period, and the process is still a vital one. To affirm the truth of this statement it is only necessary to watch, at SOLLAC, a converter dealing with 50–55 tons of iron in a quarter of an hour.

Nevertheless, despite its numerous advantages, basic Bessemer steel has long been denied certain applications thought to be too important or arduous for it to be successful. Happily recent modifications in operating methods, most of them involving to a lesser or greater extent the use of oxygen, have enabled basic Bessemer steel to conquer these fields. That is why French steelworks are now equiped with oxygen producing installations.

Other equipment at present being tested or installed is designed to make the operation of tapping basic converters almost completely automatic, and this should produce a greater consistency in quality.

So far as open-hearth steel is concerned, production has been increased above all by the completion of several large new shops, especially at USINOR and at SOLLAC, and by the enlargement of many other steelworks. The use of fuel oil is being developed at some plants. Certain works are planning to replace their open-hearths with large electric furnaces. Although at the moment this is a question for individual works alone, this changeover may have to be considered on a more general scale in the future if the production of cheap electric power develops.

Problems of this nature can moreover be studied on a co-operative level much more easily now that the structure of the industry has been changed : side by side with the important de Wendel company, which recently celebrated its 250th anniversary, are to be found the new and powerful companies created by fusion of interests and regrouping of works, such as USINOR, SIDELOR, and Lorraine-Escaut, which are all approaching an annual production of two million metric tons of steel.

Other companies have similarly established connections that are often very strong. For example, the Société Métallurgique de Normandie and the Société Métallurgique de Knutange have very close links with the Société Schneider du Creusot, and elsewhere a group of four of the principal undertakings in the Saint-Etienne area has recently been formed under the title ' Compagnie des Ateliers et Forges de la Loire.'

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It is hoped that this rapid survey has allowed readers to enter into the atmosphere of the French iron and steel industry. They will have found that industry to be imbued with the inspired ideas of Sir Henry Bessemer, put into practice by Sidney Gilchrist Thomas, just as in the United Kingdom the influence of Pierre Emile Martin is dominant. These are examples of the fruitful exchange of ideas between the two sides of the Channel.

# Studies on a 10-cwt Arc Furnace

*By W. H. Glaisher, B.Sc., A.I.M., M. Preston, Assoc. Met., A.I.M., and J. Ravenscroft, B.Sc., Grad.I.E.E., A.R.T.C.S.*

SYNOPSIS

This paper describes work carried out with a 10-cwt Héroult arc furnace to determine the most economical operating conditions. The study was chiefly on electricity and electrode consumption and on roof wear, and was concerned principally with the melting phase of the process, although some of the conclusions obtained also apply to the refining stage. Conditions of operation were closely standardized and enough heats were made under each set of conditions for the significance of any differences in the results obtained to be assessed. The major independent variables were power input during melting, electrode size, and the height of the roof. Power input during melting was varied from 200 kW (very low for the furnace size) to 550 kW (very high). Increased power input (i) reduced electricity consumption, (ii) increased roof wear, (iii) had little effect on electrode consumption. The electrode sizes used were 4 in. dia. (normal for this size of furnace) and 7 in. (very large). By comparison the smaller electrodes resulted in (i) reduced electricity consumption, (ii) reduced electrode consumption, (iii) reduced roof wear.

Two different roof heights were obtained by designing the furnace so that the top section of the side walls could readily be removed or replaced as one unit. Neither roof level could be regarded as more typical of normal practice than the other. By comparison the low roof (i) very slightly reduced electricity consumption, (ii) reduced electrode consumption, (iii) increased roof wear.

For given conditions electrode consumption was found to be closely proportional to the surface area of electrode exposed within the furnace, indicating the greater importance of oxidation losses over the whole hot surface, as compared with the losses at the arcing point.

Roof wear was shown to be closely related to the maximum temperature reached by the inside surface of the roof. If arc-furnace roof-temperature measurement can be developed to make it routine practice on production furnaces, the detrimental effects of high power input during melting and of other adverse conditions could be reduced or eliminated.

Heat balances on the furnace under two sets of conditions were made, together with a partial study of the electrical characteristics of the installation.

The application of the results to production furnaces is discussed and it is concluded that there is a good case for production-furnace trials on several aspects of the work. 1257

## Introduction

THE ELECTRIC PROCESS SUB-COMMITTEE of B.I.S.R.A. decided in 1948 to install a small arc furnace in the laboratories then being planned at Hoyle Street, Sheffield; it came into operation in June, 1952. The principal object was to enable studies of the chemistry, metallurgy, and economics of the electric process to be made more easily than is possible on a production furnace, and without the expense and interruption of production which would be entailed were these experiments carried out on such a furnace. The furnace had to be of a size that could be manned and operated without too great expense, but large enough to give results which could be regarded as a useful indication of performance under similar conditions with industrial-size furnaces.

The furnace installed was of 10 cwt capacity and was supplied by the Electric Furnace Co., Ltd. Figure 1 shows the principal dimensions. The furnace is in most ways of conventional Héroult design, but it incorporates a number of special features which widen the range over which research can be conducted. The shell is 5 ft in diameter and the height of the walls, from sill to roof ring, can be varied from 1 ft 5 in. to 2 ft 2 in. in 3-in. steps by the inclusion of additional rings. The furnace bottom is of austenitic stainless steel in order that induction stirring equipment can, if required, be fitted later. Especially high maximum forward tilt of 60° is provided, with 15° reverse tilt. There is provision for the use of two electrode sizes, 4 in. and 7 in. diameter, and for considerable variation of pitch circle diameter. The electrodes are controlled by a rotadyne installation.

The furnace transformer, supplied by the Metropolitan-Vickers Electrical Co., Ltd., is of 500 kVA nominal capacity and is larger than those on many existing 10-cwt furnaces, so that the effect of especially high-power input levels can be investigated. It has eight voltage tappings, ranging from 64 to 180 V, the four higher tappings being with the primary windings delta-connected and the lower tappings with the primary connected in star. The secondary windings are delta-connected. Incorporated with the transformer is a tapped reactor, and the amount of supplementary reactance in circuit on each voltage tap can be varied from 0 to 100% of the maximum value, in $33\frac{1}{3}$% steps.

The instrumentation of the furnace consists of a voltmeter, ammeter, power-factor meter, and kWh meter on the primary side of the transformer, and three ammeters (one in each phase), a voltmeter, and a wattmeter on the furnace side. A recording wattmeter and a triplex recording ammeter have also recently been installed on the furnace.

The furnace bottom is rammed from graphitized dolomite and the side walls are of 9-in. chrome–magnesite brick. Silica roofs 9 in. thick have been used, but in the recent trials these have been replaced by 9-in. firebrick.

In planning the work for which the furnace was to be used, two principal directions could be taken. One

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The authors are at the Association's Sheffield Laboratories.

was to make the metallurgical and chemical aspects of the steelmaking process the chief study, with the object of improving steel quality or improving the ease with which a given quality could be obtained. There is much call for work of this type, because specifications continually become more restricting. To be profitable, this involves steelmaking under very closely controlled conditions.

The other aspect was to attempt to improve the electric furnace process from an economic point of view, thereby widening the range of steels for which it could be used. The electric process is generally slightly more expensive to operate than the open-hearth process, but fairly small savings would make it much more competitive for the ordinary steels which represent the greater part of steel output. Any such savings would apply equally to the production of any quality of steel.

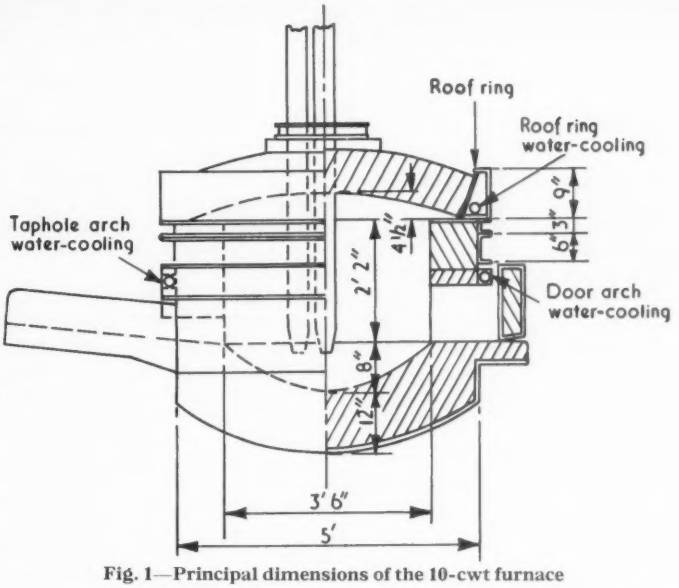


**Fig. 1—Principal dimensions of the 10-cwt furnace**

It was decided to investigate some of the economic aspects of electric-furnace operation first, since the chemical and metallurgical aspects had been and were being studied continuously both in the works and in various laboratories, whereas much less work had been done on such matters as electricity and electrode economy.

## OBJECTS OF THE PRESENT INVESTIGATION

When the costs of converting steel scrap into ingots by the electric process are examined, the largest two items are found to be the costs of electricity and electrodes. For example, in estimates of costs in both British and U.S. practice published recently,[1, 2] these items account for 30% and 15% respectively of the total conversion costs. They are the two items which can most readily be studied on the experimental furnace. The chief objects of the present investigation have therefore been to determine the main factors governing the consumption of electricity and electrodes. Attention has also been given to refractory wear, particularly of the roof.

It was clear at the outset that for the purposes in hand the steelmaking operation could be divided into two stages, melting and refining. The costs of the refining stage depend largely on its duration, which in turn depends on the chemistry of the process, and this has been and is being studied by many workers. On the other hand, the melting stage has been somewhat neglected. It was therefore decided that initially the work should be directed to the costs of melting, though it was clear that some of the results obtained would apply to the refining stage also. Since it was not possible to determine with accuracy the exact point at which melting was completed, the period studied was that from power on until the bath reached a standard temperature of 1600° C; this value was chosen because there would then be no risk of unmelted scrap remaining on the furnace bottom.

## PROGRAMME OF TRIALS UNDERTAKEN

In keeping with the desire to start with as few pre-conceived ideas as possible, the work on the 10-cwt arc furnace was begun with supervising and operating staff possessing extremely limited experience of electric-furnace operation. After an initial running-in period for both the furnace and the operators, the work was planned as series of heats, or 'trials,' each with definite objectives. In the early trials these objectives were limited, so that those concerned might become more fully familiar with the techniques

**Table I—LIST OF TRIALS**

| Trial No. | No. of Heats | Short Runs (*S*) or Continuous (*C*) | Roof Height (*L* = low, *H* = high) | Scrap (*T* = tube, *P* = plate) | Charge Weight, cwt | Electrode Size, in. | Power Input Levels | Observations on: |
|---|---|---|---|---|---|---|---|---|
| 1 | 28 | *S* | *H* | *T* | 7 | 4 | 4 | Electricity consumption |
| 2 | 20 | *S* | *L* | *T* and *P* | 10 | 4 | 2 | |
| 3 | 48 | *S* | *L* and *H* | *T* and *P* | 7 and 10 | 4 | 2 | |
| 4 | 24 | *C* | *H* | *T* | 10 | 4 | 2 | Electricity and electrode consumption, roof wear and roof temperature |
| 5 | 12 | *C* | *L* | *T* | 10 | 4 | 2 | |
| 6 | 48 | *C* | *L* and *H* | *T* | 10 | 4 and 7 | 2 | |

required. As experience was gained, trials covering more variables were undertaken.

The complete series was not planned at the start; the programme was determined stage by stage as the relative importance of the various factors was shown by the results obtained.

In all trials the order in which the heats were carried out was chosen to avoid any bias in the results due to unplanned variations in the behaviour of the furnace. The most obvious of such changes was the condition of the furnace refractories, which could not be kept standard throughout the work. Other changes could be variation in the raw materials used, in the quality of the electrodes, in the efficiency of the electrode controllers and other equipment, and in that of the operators. Because of the possibility of these unplanned and mostly unrecorded variabilities, deliberate variables have in general been examined within each trial only and comparisons between the various trials avoided. The major trials were numbered and are listed in Table I.

For the first three trials the furnace was operated on a single shift only, normally making four heats during this time. This method has the disadvantage that very variable electricity consumptions are obtained on the first heats of the day, so that the results from the first heats, for electricity consumption investigations, are not used. The furnace becomes increasingly efficient through the day, so that even the second, third, and fourth heats are not directly comparable and allowance has to be made for this in studying the results obtained. In the following trials, therefore, the furnace was run continuously, using three shifts of operators.

Two heat balances, each over a series of three heats, were made on low- and high-power heats after trial 6, starting with the furnace thoroughly hot from several previous heats.

The resistivity of all electrodes was measured and only those within 900–1200 $\mu\Omega$-cm were used.

## RANGE OF VARIABLES USED AND MEASUREMENTS MADE

### The Independent Variables

*Power Input*

A steady power input is not obtained during melting down owing to constant variations in the lengths of the arcs as the scrap melts. It was expected, however, that for a given voltage tap and current setting of the electrode regulators, the average input (from power on until 1600° C was reached) of each heat in a series of heats made under constant conditions would show little variation. This did not prove to be the case, variations up to $\pm$ 10% of the mean occurring. Thus although certain nominal power input levels were used in each trial, the actual inputs varied over a range. During the first trial mean inputs varying from 200 to 500 kW were used, and the upper limit was later extended to 550 kW. This upper limit represented an overload of about 50% on the continuous rating of the furnace transformer; however, the total melting time when using this power input was only about 40 min, which was well within the permissible duration of overload for this type of transformer.

The control settings corresponding to the different power-input levels used in the trials are shown in Table II.

The power input for each heat was calculated from the kWh used between power-on and 1600° C, divided by the net time taken. No changes in voltage or current settings were made during this period. The net time was the total time less stoppages for pulling unmelted scrap off the banks and for rabbling, or other reasons. Stoppages for other reasons were unusual, and if they were extensive the result of the heat was discarded. The power was off and the door open for standard lengths of time for both pushing scrap in and rabbling, irrespective of the actual time required, to prevent variations in heat loss during these operations. The total time the power was off in each heat for these two operations was 4 min.

The method of determining exactly when 1600° C was reached is described below under the sub-heading " Electricity Consumption."

*Type of Scrap*

The type of scrap used in production furnaces is well known to influence electrode breakage and roof wear, but its effect on electricity consumption is not known. In the early trials only this latter item was studied, and it was important to know whether a standard charge was necessary. In trials 2 and 3, therefore, types of scrap of widely different bulk density were compared. In both trials one type was mild-steel tube scrap in 6–9-in. lengths and of mixed diameter ($\frac{1}{2}$–3 in.); the second type was thin high-carbon plate scrap in small pieces in trial 2 and heavy mild-steel plate scrap, in pieces about 6 in. square, in trial 3. When using the tube scrap it was necessary to place a lump of heavy scrap on the hearth under each electrode to prevent the electrodes boring down too rapidly, and $\frac{1}{2}$-cwt ' cheeses ' were cast and used for this purpose.

As shown later, the type of scrap used was found to be important and it was fortunately possible to arrange for adequate supplies of the tube scrap, reproducible over long periods. This material, therefore, with three ' cheeses ' has been used as a standard charge since these early trials.

*Charge Weight*

The charge weight was varied only in the early stages. The effect of undercharging with only 7 cwt, instead of the normal 10 cwt, was examined in trial 3, and subsequent trials were all on 10-cwt charges.

*Roof Height*

The roof was used only at the highest and lowest

**Table II—CONTROL SETTINGS**

| Voltage Tapping | Load Setting | Open Circuit Volts | Furnace Current During Melting, A | Average Power Input to 1600° C, kW | Used in Trials |
|---|---|---|---|---|---|
| No. 4 | No. 4 | 104 | 1200 | 230 | 1 |
| No. 5 | No. 5 | 110 | 1500 | 250 | 1, 2, 3, 4, 6 |
| No. 6 | No. 6 | 130 | 1900 | 375 | 1 |
| No. 7 | No. 7 | 153 | 2100 | 490 | 1, 2, 3, 5 |
| No. 8 | No. 8 | 180 | 2300 | 550 | 4, 5, 6 |

levels, the two extension rings bolted together and bricked as one unit being added or removed as necessary; the height of the roof ring above the sill was 1 ft 5 in. or 2 ft 2 in. The two levels were designated simply ' low roof ' and ' high roof.'

*Electrode Diameter*

In most trials 4-in. dia. graphite electrodes on a 12-in. dia. pitch circle have been used, but in trial 6 they were compared with 7-in. dia. electrodes on a 20-in. dia. pitch circle, this pitch circle being the smallest which would accommodate the electrode holders. 4 in. is the normal electrode diameter for a 10-cwt furnace. In the main trials when using this size the maximum current density was about 180 A/in$^2$, although in other tests up to 240 A/in$^2$ has been used. These current densities tend to be high compared with those generally used in production furnaces, even making allowance for the increase in current density permissible with small electrodes. Current densities with the 7-in. electrodes were, however, unusually low.

**The Dependent Variables**

*Electricity Consumption*

As stated earlier, the part of the heats studied has been from power-on until the charge reaches 1600° C. Since continuous temperature measurements were impracticable, and the chance of making an immersion temperature measurement at exactly 1600° C was small, the rate of temperature rise of the bath when in the region of 1600° C has been determined for various conditions of operation (e.g. for different power inputs, charge weights, and roof heights), together with the electricity consumption per minute for the varied conditions. From these data, provided that a measurement is made when the temperature is within the range 1550–1650° C, the time and energy consumption required for a temperature of exactly 1600° C can be calculated to within 1 min and 10 kWh, which was considered to be sufficiently accurate. This removes the need for more than one temperature measurement for this purpose on most heats.

*Electrode Consumption*

Electrode consumption was not studied in detail until trial 4, when the procedure of running complete trials without allowing the furnace to cool down was started. From this point onwards, in order to make such a study convenient, the trials were arranged so that three consecutive heats were made under each set of conditions, alternative sets of electrodes being used for each group of three heats. The electrodes could thus be allowed to cool down before weighing, without delaying the succeeding heat. In trial 6 the electrodes were also measured at intervals along their length so that the surface area exposed within the furnace could be calculated.

*Roof Temperature*

Temperature measurements at the inside face of the roof were made by means of platinum/platinum–rhodium thermocouples in fused alumina sheaths. The sheaths were arranged so that the tips projected about ½ in. through the roof, and the two wires were coiled close to the hot junction to minimize heat loss from the junction by conduction along the wires. Initially, thermocouples were placed at five points so that the temperature distribution over the roof could be examined, and subsequently only one thermocouple at the hottest point was used, the output e.m.f. being recorded on a potentiometer. The life of the thermocouple and sheath was generally 1–2 days when the furnace was operated continuously, and this was satisfactory for the purpose in hand since sheath and couple could readily be replaced.

*Roof Wear*

The main purpose of making roof wear measurements was to determine the occurrence and extent of the reported serious increase in roof wear, occurring with high power input. Measurements were made only by weighing the roof, which was carried out from trial 4 onwards between each set of three heats, using a crane scale. To facilitate weighing, the asbestos-covered water connections to the roof ring and electrode coolers were replaced before trial 6 by light rubber pipes, and it was then possible to weigh the roof with sufficient accuracy without disconnecting these pipes, provided that during weighing the roof was always lifted to the same height and not displaced laterally. The electrodes were, of course, removed first. The roof weighings were then accurate to ± 2 lb.

## TABULATION OF RESULTS

The results of all trials except No. 1 are presented in Tables III–VII, partly in summarized form to save space. This method is used since the results from the same trials are used in each of the three following sections, and much duplication would otherwise result. To illustrate the degree of reproducibility obtained between similar heats, the results of trials 3 and 6 are presented in full. Results from trial 1 are not tabulated since they are shown adequately by Figs. 2, 3, and 5.

## ELECTRICITY CONSUMPTION

In this section the effects of the independent variables on electricity consumption during melting are studied in turn; their effects on the other dependent variables are covered in later sections. The effect of discontinuous running and of the condition of the roof and walls on electricity consumption are also described.

**Effect of Power Input**

The experimental work in trial 1 was designed to obtain a relationship between power input and electricity consumed. It was carried out on 28 heats, using a charge of 7 cwt instead of the standard 10 cwt,

**Table III—RESULTS OF TRIAL 2**

**10-cwt charges: 4-in. electrodes: roof at low level. Each figure is the mean of 5 heats: two 2nd, two 3rd, one 4th in the day. Electricity consumptions in kWh/ton to 1600° C**

| Electricity Consumption | | |
|---|---|---|
| **Power Input** | **Tube Scrap** | **Light Plate Scrap** |
| **High (499 kW)** | **782** | **766** |
| **Low (254 kW)** | **994** | **998** |

## Table IV—RESULTS OF TRIAL 3

4-in. electrodes: plate scrap of heavy type: electricity consumptions in kWh/ton to 1600° C
Mean power inputs: high-power heats 490 kW, low-power heats 253 kW

| Heat No. of Day | High Roof | | | | | | | | Low Roof | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High Power | | | | Low Power | | | | High Power | | | | Low Power | | | |
| | Tubes | | Plate | | Tubes | | Plate | | Tubes | | Plate | | Tubes | | Plate | |
| | 7 cwt | 10 cwt | 7 cwt | 10 cwt | 7 cwt | 10 cwt | 7 cwt | 10 cwt | 7 cwt | 10 cwt | 7 cwt | 10 cwt | 7 cwt | 10 cwt | 7 cwt | 10 cwt |
| 2 | 709 | 784 | 829 | 752 | 946 | 966 | 1028 | 1056 | 774 | 702 | 817 | 798 | 866 | 988 | 1017 | 922 |
| 3 | 789 | 700 | 806 | 714 | 800 | 976 | 906 | 870 | 834 | 658 | 783 | 726 | 862 | 808 | 990 | 808 |
| 4 | 646 | 596 | 691 | 714 | 840* | 876 | 977 | 908 | 746 | 650 | 771 | 700* | 800 | 650 | 954 | 868 |
| Av. | 715 | 693 | 775 | 727 | 862 | 939 | 970 | 945 | 785 | 670 | 790 | 741 | 843 | 815 | 987 | 866 |

* These two experiments were omitted from the series for various reasons, and the figures given have been calculated from the other values using the differences between the variables obtained from the rest of this trial and from the other trials, in order to balance the Table and facilitate statistical analysis of the results. The significance of the results will, of course, be slightly reduced by this, but it is a better alternative than that of omitting all the 4th heats from the statistical analysis

and the roof was at the highest level. The heats were second, third, and fourth in each day and are so indicated on the graphs of results. Four power-input levels were used and these inputs were maintained until the standard temperature of 1600° C was reached. Figure 2 shows the results obtained. Part of the scatter is due to real differences between second, third, and fourth heats and it can be reduced by correcting the figures obtained to a common basis. Results obtained in this and subsequent trials showed that, on average, second heats of the day used about 10% more electricity than fourth heats, and third heats of the day about 4% more than fourth heats. Figure 3 gives the results that might have been expected had all the heats been fourth heats of the day, and indicates a hyperbolic relationship between power input and electricity consumption. As might be expected, increasing power input reduces the consumption, at first rapidly and then more slowly at higher input levels. At the highest input level used in this trial (about 500 kW) the curve is still falling. The results of later trials on electricity consumption, comparing only two levels of power input, are summarized in Table VIII; they confirm the trends in Figs. 2 and 3.

Owing to variations in the condition of the refractories and to the fact that some trials were carried

## Table V—RESULTS OF TRIAL 4

10-cwt tube scrap charges: 4-in. electrodes: roof at high level:
furnace operated continuously: silica brick roof

| Heat Nos. | Power Input, kW | | kWh/ton to 1600° C | Electrode Consumption, lb/ton | Age of Roof in Heats | Change in Wt. of Roof, lb per 3 heats |
|---|---|---|---|---|---|---|
| | Nominal | Actual Mean | | | | |
| 233–235 | 250 | 254 | 927 | 11·5 | 3–5 | + 6 |
| 236–238 | 250 | 256 | 811 | 10·3 | 6–8 | +16 |
| 239–241 | 550 | 537 | 747 | 10·8 | 9–11 | − 6 |
| 242–244 | 550 | 533 | 662 | 8·0 | 12–14 | − 6 |
| 245–247 | 550 | 570 | 657 | 9·3 | 15–17 | − 8 |
| 248–250 | 550 | 562 | 685 | 10·0 | 18–20 | − 5 |
| 251–253 | 250 | 255 | 851 | 7·7 | 21–23 | − 3 |
| 254–256 | 250 | 252 | 815 | 7·0 | 24–26 | + 6 |

## Table VI—RESULTS OF TRIAL 5

10-cwt tube scrap charges: 4-in. electrodes: roof at low level:
furnace operated continuously: silica brick roof

| Heat Nos. | Power Input, kW | | kWh/ton to 1600° C | Electrode Consumption, lb/ton | Age of Roof in Heats | Change in Wt. of Roof, lb per 3 heats |
|---|---|---|---|---|---|---|
| | Nominal | Actual Mean | | | | |
| 264–266 | 490, 550<br>490 | 528 | 701 | 7·2 | 33–35 | − 7 |
| 267–269 | 550, 490<br>550 | 529 | 685 | 7·5 | 36–38 | −27 |
| 270–272 | 550 | 537 | 660 | 7·7 | 39–41 | − 8 |
| 273–275 | 490 | 485 | 632 | 7·2 | 42–44 | Nil |

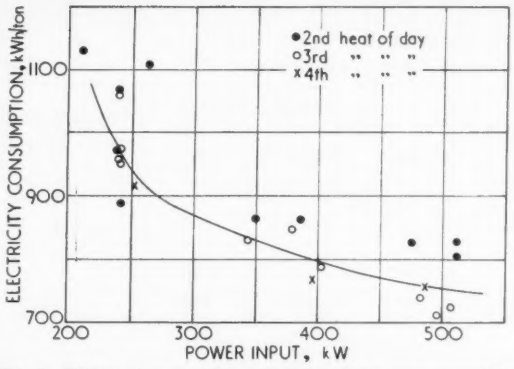


**Fig. 2—Effect of power input on electricity consumption: 7-cwt heats, trial 1**

out on a 24-h basis and in others three or four heats only were made each day, large variations in energy consumption between the trials were found for apparently similar conditions. Thus it is not generally possible to compare the results of the trials.

In trial 5 two high power inputs, approximately 490 and 550 kW, were compared. The increase from 490 to 550 kW resulted in a decreased electricity consumption of 14 kWh/ton. Although this difference was not statistically significant on the number of results obtained, it is of the order to be expected from a continuation of the curves in Figs. 2 and 3. The energy consumptions for 490-kW input in trials 3 and 5 are different because of the different conditions of operation.

Trials 1, 2, 3, 4, and 6, in all of which the results were statistically significant on a high level, show that by doubling the power input electricity consumption in melting is reduced by 15–20%. The improvement tends to be greatest on heats made under the single-shift working conditions of trials 2 and 3, and for continuous operation it averages about 16%. More detailed study of the results shows that this applies to approximately the same extent whatever the conditions, e.g. high roof or low, 7- or 10-cwt charges, 4- or 7-in. electrodes.

Figure 4 shows the relationship between power

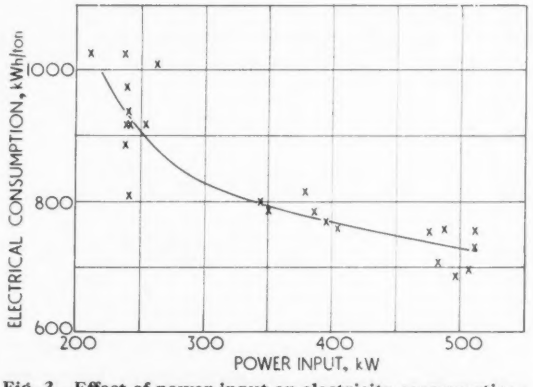


**Fig. 3—Effect of power input on electricity consumption: 7-cwt heats, trial 1. (Figures corrected to make all equivalent to 4th heat of day)**

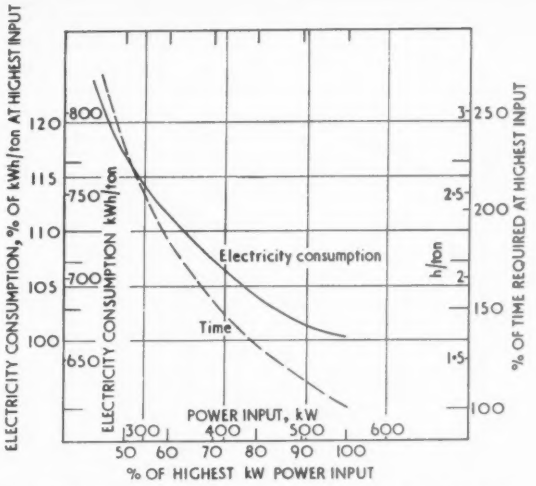


**Fig. 4—Relationships between power input and electricity consumption in melting and melting time for the 10-cwt furnace**

input and electricity consumption finally obtained from a study of all results under conditions of continuous operation. In this Figure power input is plotted both as kilowatts and as percentage of the highest power input (550 kW on the No. 8 voltage and current settings) while electricity consumption is plotted as kWh/ton and percentage of kWh/ton required at the highest power input. It is thus possible to see at a glance what increase in electricity consumption results from a given percentage reduction in power input below 550 kW. Thus power inputs 10%, 20%, 30%, 40%, and 50% below the highest result in 1·5%, 4%, 7%, 11%, and 16% increases in electricity consumption. These differences apply, of course, only to the electrical energy consumed during the melting and heating to 1600° C period. Assuming that about one-third of the electricity is consumed during the later stages of the heat, as can be seen from the 1949 report on electric furnace practice in Great Britain,[3] the increases over the whole heat would be about two-thirds of these figures.

Of great importance under many conditions is the saving in time obtained when using high power input. Time per ton is also plotted in Fig. 4 both in hours and as percentage of the time with the highest power input. It will be seen that inputs 10%, 20%, 30%, 40%, and 50% below 550 kW result in melting times 13%, 30%, 52%, 85%, and 130% greater than that with 550 kW input. The decreased energy consumption found at increasing power inputs up to 550 kW is due to the lesser time taken by the heats, which results in lower heat losses. This is confirmed by Fig. 5, which shows the energy used plotted against the total time taken for the charge to reach 1600° C for the same heats as in Figs. 2 and 3.

The maximum power that can be put into the furnace is controlled by the size of the transformer, the supplementary reactor, and the various impedances in the furnace circuit (busbars, cables, etc.). From short-circuit tests on the furnace, when the

## Table VII—RESULTS OF TRIAL 6

**10-cwt tube scrap charges: furnace operated continuously: firebrick roof**

| Heat No. | Roof Height | Electrode Size, in. | Mean Power, kW | Net Time to 1600° C, min | kWh/ton to 1600° C | Electrode Consumption | | | Change in Roof Weight, lb per 3 heats |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | lb/ton | lb/ton/ft² | lb/h | |
| 341 | | | 249 | 95 | 790 | | | | |
| 342 | High | 4 | 256 | 80 | 682 | 6·3 | 0·73 | 2·83 | + 5 |
| 343 | | | 251 | 79 | 660 | | | | |
| 344 | | | 460* | 41 | 628 | | | | |
| 345 | High | 4 | 600 | 31 | 620 | 7·0 | 0·81 | 3·82 | − ½ |
| 346 | | | 549 | 32 | 586 | | | | |
| 347 | | | 521 | 42 | 730 | | | | |
| 348 | Low | 4 | 550 | 36 | 660 | 5·5 | 0·76 | 3·75 | −23½ |
| 349 | | | 574 | 33 | 632 | | | | |
| 350 | | | 260 | 83 | 720 | | | | |
| 351 | Low | 4 | 246 | 80 | 656 | 6·75 | 1·00 | 1·94 | −10½ |
| 352 | | | 239 | 103 | 820 | | | | |
| 363 | | | 249 | 112 | 928 | | | | |
| 364 | Low | 7 | 177 | 92 | 850 | 10·5 | 0·86 | 3·49 | −11 |
| 365 | | | 266 | 79 | 700 | | | | |
| 366 | | | 543 | 44 | 796 | | | | |
| 367 | Low | 7 | 503 | 41 | 688 | 8·5 | 0·68 | 4·61 | −28 |
| 368 | | | 514 | 42 | 720 | | | | |
| 369 | | | 518 | 55 | 950‡ | | | | |
| 370 | High | 7 | 529 | 44 | 776‡ | 11·8 | 0·74 | 5·95 | −11 |
| 371 | | | 518 | 42 | 726 | | | | |
| 372 | | | 262 | 125 | 1094 | | | | |
| 373 | High | 7 | 260 | 86 | 746 | 14·3 | 0·93 | 3·63 | −10½ |
| 374 | | | 250 | 99 | 824 | | | | |
| 375 | | | 262 | 101 | 882 | | | | |
| 376 | High | 7 | 257 | 103 | 884 | 12·8 | 0·87 | 3·22 | + 1 |
| 377 | | | 244 | 99 | 804 | | | | |
| 378 | | | 532 | 44 | 780 | | | | |
| 380 | High | 7 | 563 | 39 | 732 | 17·75 | 1·27 | 6·94 | − 6 |
| 381 | | | 504 | 40 | 672 | | | | |
| 382 | | | 528 | 47 | 828 | | | | |
| 383 | Low | 7 | 511 | 43 | 732 | 11·3 | 0·94 | 5·70 | −14½ |
| 384 | | | 532 | 36 | 638 | | | | |
| 385 | | | 271 | 111 | 1002 | | | | |
| 386 | Low | 7 | 269 | 88 | 788 | 12·0 | 1·03 | 3·00 | −21 |
| 387 | | | 242 | 105 | 848 | | | | |
| 392 | | | 574 | 34 | 650 | | | | |
| 393 | Low | 4 | 578 | 33 | 636 | 6·8 | 1·07 | 4·22 | − 9½ |
| 394 | | | 565 | 33 | 622 | | | | |
| 395 | | | 238 | 97 | 768 | | | | |
| 396 | Low | 4 | 239 | 86 | 686 | 9·8† | 1·57 | 2·64 | −10½ |
| 397 | | | 220 | 101 | 740 | | | | |
| 398 | | | 247 | 118 | 972‡ | | | | |
| 399 | High | 4 | 249 | 97 | 804‡ | 9·0 | 1·06 | 2·39 | − 3 |
| 400 | | | 252 | 86 | 722 | | | | |
| 401 | | | 545 | 34 | 618 | | | | |
| 402 | High | 4 | 547 | 34 | 620 | 7·2 | 0·85 | 4·21 | − 5 |
| 403 | | | 545 | 36 | 654 | | | | |

* Voltage wrongly set for part of the heat

† 2 breakages made the estimated electrode consumption for this set of 3 heats inaccurate, hence it was omitted from the subsequent analysis

‡ These heats had high electricity consumptions because they were the first heats after the wall extension was inserted. For purposes of studying the data it has been assumed that their consumptions were the same as for comparable 1st heats of series of 3 made under similar conditions, but when the wall extension had been in place for the previous heats

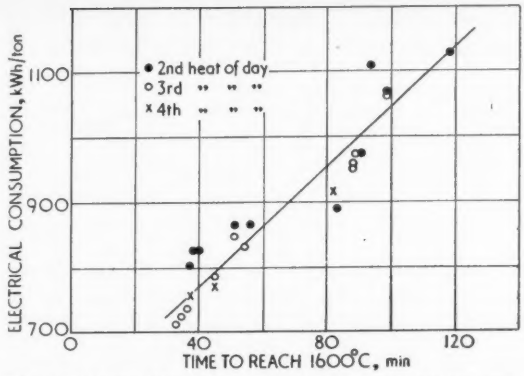


**Fig. 5—Effect of time taken in melting on electricity consumption : 7-cwt heat, trial 1**

charge was molten, and from meter observations taken during normal running, it was deduced that the furnace maximum power input, averaged over the melting period, is limited to about 620 kW on the No. 8 voltage tap, the corresponding furnace current being about 3000 A. However, the characteristics of the electric-arc furnace[4] are such that when an increase in furnace current increases the circuit power, it does not necessarily give an increase in useful power into the furnace, i.e. in arc power.

Typical electric arc furnace characteristics, for a given voltage tapping, are shown in Fig. 6. The power into the furnace circuit increases with current up to a maximum value, when with further increase of current the kilowatts decrease. The arc-power/furnace-current characteristic is similar, but lies below the circuit power curve and reaches a maximum value at a current slightly less than the current corresponding to maximum circuit power. The current for maximum arc power is termed the *optimum current*. Electrical efficiency and circuit power-factor fall off with increase in current.

For the 10-cwt experimental furnace, the optimum current on the No. 8 voltage tap is about 2700 A, and the corresponding circuit power input (averaged over the melting period) is about 600 kW. The highest power used in the trials was 550 kW, when operating the furnace on the No. 8 voltage tap and No. 8 load setting, the normal highest power input setting, giving 130 V on load at 2200 A. By modifying the furnace electrode-control circuit it is possible to increase the furnace current on this setting to 2700 A, when the furnace would be operating at optimum current. However, although this should decrease the melting

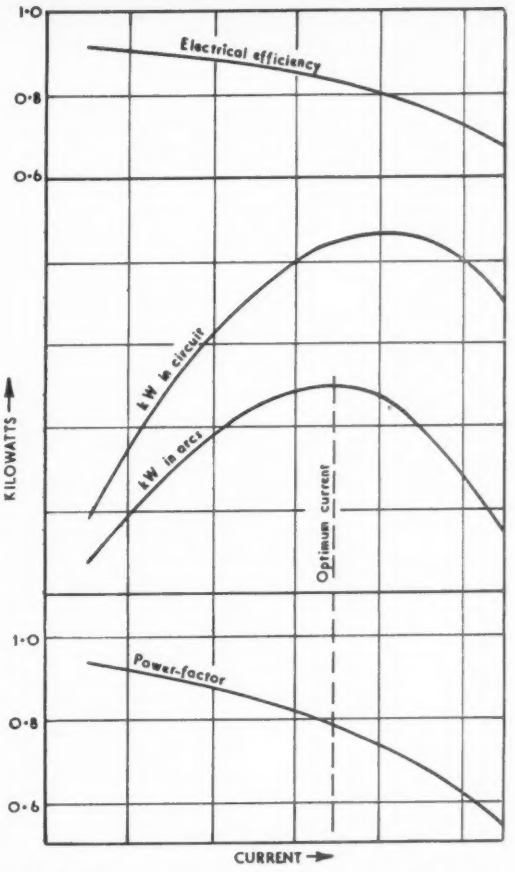


**Fig. 6—Typical electric-arc furnace characteristics**

time, as would be expected from Fig. 4, and so reduce the heat losses, the effect on electricity consumption would be negligible because of the correspondingly large decrease in electrical efficiency for a small increase in arc power, when working on the flat top portion of the characteristic.

Compared with modern practice, 550 kW input is very high for a 10-cwt charge, but it is probable that with a higher transformer capacity the overall efficiency of the installation would be further increased, as there is no reason to suppose that a maximum in the *thermal* efficiency of the furnace itself has been reached.

**Table VIII—SUMMARIZED ELECTRICITY CONSUMPTION RESULTS, TRIALS 2–6**

| Trial No. | Results in Table No. | Mean Power Input Levels, kW | | Mean Electricity Cons., kWh/ton at: | | Improvement at the Higher Power, % | Short Runs (*S*) or Continuous (*C*) |
|---|---|---|---|---|---|---|---|
| | | Low | High | Low Power | High Power | | |
| 2 | III | 254 | 499 | 996 | 774 | 22 | *S* |
| 3 | IV | 253 | 490 | 903 | 737 | 18 | *S* |
| 4 | V | 253 | 549 | 851 | 688 | 19 | *C* |
| 5 | VI | 493 | 546 | 676 | 662 | 2 | *C* |
| 6 | VII | 252 | 538 | 800 | 688 | 14 | *C* |

**Table IX**

**COMPARISON OF TYPES OF SCRAP**

**Electricity consumption, kWh/ton**

| Trial No. | Tube Scrap | Plate Scrap | Ratio $\frac{\text{Plate Scrap}}{\text{Tube Scrap}}$ |
|---|---|---|---|
| 2 | 888 | 882 | 0·99 |
| 3 | 790 | 850 | 1·075 |

It should be pointed out, however, that increases in power input may affect maximum demand charges. This point is discussed later.

**Effect of Type of Scrap**

Half the heats in trials 2 and 3 were made with tube scrap and half with plate scrap. Tube-scrap charges fill the bulk of the furnace space. The plate scrap used in trial 2 was about $\frac{1}{8}$ in. thick and was of high carbon content and, whilst occupying less space than the tube scrap, it did not pack as well as the heavier mild-steel plate scrap used in trial 3. This type of scrap occupied much less than half of the furnace space. The results are given in Table IX.

The result from trial 3, which was of 48 heats, was statistically significant on the 0·1% level whereas that of trial 2, on 20 heats only, was not significant. In the latter instance the issue was in any case confused by the difference in melting point of the two types of scrap, and its result has therefore been disregarded. The lower electricity consumption when using tube scrap than when using plate scrap in trial 3 can be explained by the fact that with the tube scrap the electrodes burrow rapidly into the charge, and from that point until most of the scrap is melted nearly all the heat produced in the arcs is absorbed directly in the scrap. With the plate scrap the electrodes do not burrow into the charge nearly so readily and more radiation to the roof and the walls occurs throughout the melting period.

The much lower electricity consumption using tube scrap in trial 3 than in trial 2 was due to rebricking the walls and putting on a new roof just before trial 3. Under similar furnace conditions the plate scrap used in trial 3 would evidently have required much more electricity than that in trial 2.

**Effect of Charge Weight**

The effects of undercharging the furnace were examined during trial 3 with the following results (kWh/ton):

| 10 cwt | 7 cwt | Ratio $\frac{\text{7 cwt}}{\text{10 cwt}}$ |
|---|---|---|
| 799 | 841 | 1·05 |

This difference was statistically significant on the 5% level. It has always been known that lower efficiencies are obtained with smaller charges and the results of this trial confirm this and put a quantitative value to the effect.

**Effect of Roof Height**

Direct comparisons of the effects of roof height were made in trials 3 and 6 and the results are given in Table X.

Taking the two trials together, the use of the low roof level gave a 1% reduction in electricity consumption. The difference is not statistically significant, but lower heat losses would be expected with the reduced furnace surface area when using the low roof. The difference found is not substantially different from that to be expected from the study of surface heat losses described in the section on heat balances.

**Table X**

**EFFECT OF ROOF HEIGHT ON ELECTRICITY CONSUMPTION, kWh/ton**

| Trial No. | High Roof | Low Roof | Ratio $\frac{\text{Low Roof}}{\text{High Roof}}$ |
|---|---|---|---|
| 3 | 828 | 812 | 0·98 |
| 6 | 744 | 744 | 1·00 |

**Effect of Electrode Diameter**

Comparison of 4- and 7-in. dia. electrodes was made only in trial 6. It was not possible to distribute these two variables throughout the trial, which was therefore conducted by making twelve heats with 4-in. electrodes, then 24 with 7-in., and a further 12 with 4-in. The pitch circle diameter using 4-in. electrodes was the normal one of 12 in., but for the 7-in. it had to be increased to 20 in. to allow sufficient clearance between the electrode holders. The results are shown in full in Table VII and are summarized in Table XI.

The following reasons are put forward to account for the surprisingly large mean difference of 16% in energy consumption:

(i) From data obtained during the determination of the heat balances described later, the total heat loss by conduction up 4-in. dia. electrodes is equivalent to about 2% of the electricity consumption. The 7-in. dia. electrodes have three times the cross-sectional area of the 4-in. and the heat loss will therefore probably be three times as great, equivalent to about 6% of the electricity used, an increased loss of 4%.

(ii) At the start of each heat, electrodes which are relatively cold have to be heated up to working temperature, the difference in the amount of heat required for the 7-in. as compared with the 4-in. representing about 2% of the electricity used in the heat.

(iii) A further, and possibly the major, part of the difference is due to the fact that the 7-in. electrodes are much closer to the side walls and the banks than are the 4-in., the distances from the walls being about 9 in. and 14 in. respectively. That this would increase the heat losses in this direction is confirmed by the fact that cutting of the banks adjacent to the 7-in. electrodes was appreciable, whereas it was not observed with the 4-in. electrodes.

(iv) Slightly increased heat losses in escaping gases

**Table XI**

**EFFECT OF ELECTRODE SIZE ON ELECTRICITY CONSUMPTION, FROM TRIAL 6, kWh/ton**

| Conditions | 4-in. Electrodes | 7-in. Electrodes | 7″/4″ |
|---|---|---|---|
| High roof, high power | 620 | 744 | 1·20 |
| ,, ,, low ,, | 742 | 872 | 1·17 |
| Low ,, high ,, | 656 | 734 | 1·12 |
| ,, ,, low ,, | 732 | 852 | 1·16 |
| Average | 688 | 800 | 1·16 |

might be expected with the 7-in. electrodes because of the larger roof openings.

(v) An opposing factor is the reduced electrical loss in the electrodes when using 7-in. dia. electrodes compared with 4-in. Information obtained from short-circuit tests on the furnace shows that this will be of the order of 2% of the total electricity consumption.

The net result of factors (i), (ii), and (v) is that the change in electrode size *per se* accounts for only about 4% of the 16% increase in electricity consumption found with the 7-in. electrodes. It thus appears that the accompanying change in pitch circle diameter is largely responsible for this increase, since the losses in escaping gases should not be a large proportion of the total heat loss.

### Effect of Discontinuous Running

Trials 1, 2, and 3 showed that the first four heats after starting from cold used progressively less electricity, and subsequent trials showed that there was a slight further improvement after the fourth heat. Average figures for 1st, 2nd, 3rd, and 4th heats were 53%, 12%, 6%, and 2% more than in subsequent heats made under similar conditions. This is illustrated in Fig. 7 and emphasizes the greatly increased electricity consumption resulting from working on a single-shift basis.

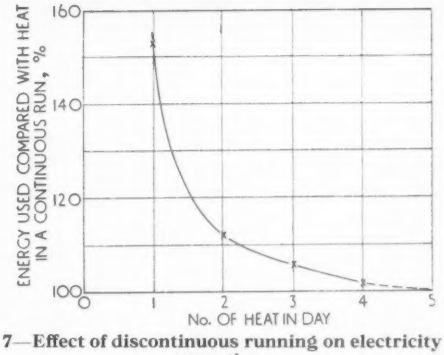


**Fig. 7—Effect of discontinuous running on electricity consumption**

### Effect of Condition of Roof and Walls

Trial 3 covered a period of 16 working days and the first 8 days were directly comparable with the second, since the programme of variables was properly balanced. The first half of the trial was within roof heat numbers 10–39* and wall heat numbers 4–33* and gave a mean electricity consumption of 801 kWh/ton, and the second half of the trial within roof heat numbers 41–89 and wall heat numbers 35–83 with a mean electricity consumption of 840 kWh/ton. From this comparison it is seen that the effect of roof and wall condition over the period studied is of the order of 5%. The roof failed shortly after the completion of this trial, while the walls remained fairly good.

Similarly the first part of trial 6 using 4-in. electrodes was directly comparable with the third part, except for the age of walls and roof. Roof heat numbers 9–20 and wall heat numbers 9–20 were covered in the first part, roof heat numbers 25–36 and wall heat numbers 60–71 in the third part. The roof was in very good condition throughout, but part of the walls had been damaged during the second part, with 7-in. electrodes. Nevertheless, the mean electricity consumption was only 2% greater in the third part, and this was well within the likely random variation.

On the other hand, very badly worn walls and roof made a large difference to electricity consumption. Both were in very bad condition in trial 2, and heats in this trial used 17% more electricity than those of trial 3 made under similar conditions, with the walls and roof in good order. As shown in the section on

* The roof life progressed from 10–39 and the wall life from 4–33 heats.

**Table XII—ELECTRODE CONSUMPTIONS IN TRIAL 6 CALCULATED FROM SETS OF 3 HEATS**

| 4-in. Electrodes | | | | 7-in. Electrodes | | | |
|---|---|---|---|---|---|---|---|
| High Roof | | Low Roof | | High Roof | | Low Roof | |
| 550 kW | 250 kW | 550 kW | 250 kW | 550 kW | 250 kW | 550 kW | 250 kW |
| (*a*) Consumption in lb/ton | | | | | | | |
| 7·0 | 6·3 | 5·5 | 6·75 | 11·8 | 14·3 | 8·5 | 10·5 |
| 7·2 | 9·0 | 6·8 | 9·8* | 17·75 | 12·8 | 11·3 | 12·0 |
| All 4-in. electrodes: 6·9 lb/ton | | | | All 7-in. electrodes: 12·4 lb/ton | | | |
| All high roof heats 10·8 ,, | | | | All low roof heats 8·5 ,, | | | |
| All high power heats 9·5 ,, | | | | All low power heats 9·8 ,, | | | |
| (*b*) Consumption in lb/ton/ft² of surface area of electrode exposed in the furnace | | | | | | | |
| 0·81 | 0·73 | 0·76 | 1·00 | 0·74 | 0·93 | 0·68 | 0·86 |
| 0·85 | 1·06 | 1·07 | ... | 1·27 | 0·87 | 0·94 | 1·03 |
| All 4-in. electrodes: 0·91 lb/ton/ft² | | | | All 7-in. electrodes: 0·92 lb/ton/ft² | | | |
| All high roof heats 0·91 ,, | | | | All low roof heats 0·92 ,, | | | |
| All high power heats 0·89 ,, | | | | All low power heats 0·94 ,, | | | |

* Two breakages one during handling) made estimation inaccurate, omitted from analysis

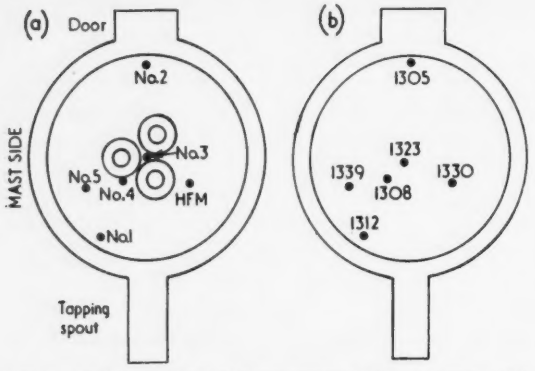


**Fig. 8—(*a*) Disposition of thermocouples in the roof ; (*b*) an example of temperature distribution with a molten bath**

determination of heat balances, heat losses through the walls are greater than those through the roof and thus wall condition is probably the more important for thermal efficiency.

As a point of interest, it may be recorded here that the total lives of the three silica-brick roofs used under the conditions of these trials were 63, 96, and 97 heats, and that the total life of the only firebrick roof discarded because of wear was 145 heats.

## ELECTRODE CONSUMPTION

The results of electrode consumption measurements made in trials 4 to 6 are given in Tables V–VII.

In trials 4 and 5, only the power input was varied deliberately. Electrode consumption in trial 4 showed a strong tendency to decrease throughout the trial irrespective of the power input. This seemed a strange result at the time, but it is now believed to be due to the fact that the trial was started with two sets of electrodes which had been used for a short period only, and were not greatly tapered. During the trial they became very much more tapered, and had therefore a reduced surface area; this is shown later in the report to be an important factor.

Trial 5 served to show that the further increase in power input used had no marked effect on electrode consumption.

The trial in which most information was obtained was No. 6. The first 12 heats were with 4-in. electrodes, the next 24 with 7-in., and the final 12 with 4-in., the other variables being properly distributed through the trial. After each three heats, the electrodes were weighed and measured at 6-in. intervals along their length, so that the surface area exposed within the furnace could be calculated. Two sets of electrodes were used, each set being weighed and measured after use while the next three heats were being made. One electrode breakage occurred in the furnace during this trial and the loss incurred in this way has been excluded (*see* section on electrode breakage). The results of the trial are re-tabulated in Table XII.

### Effect of Power Input

Electrode consumption per ton of steel or per ton of steel per square foot of surface area exposed in the furnace was practically the same at the high and low power input levels.

Consumption of electrode in pounds per hour is shown in Table XIII, which shows that rate of consumption increases almost in proportion to power input. A similar position exists when lb/h/ft² of exposed surface is calculated.

### Effect of Roof Height

The height of the furnace roof affected the electrode consumption considerably, about 20% less wear occurring with the low roof. The amount of wear was found to be proportional to the surface area exposed, as shown in Table XII*b*.

### Effect of Electrode Size

Much higher consumption per ton of steel was found with the 7-in. electrodes. The increase was again found to be approximately in proportion to the additional surface area exposed in the furnace. Thus when the consumption is calculated per square foot of surface, as in Table XII*b*, the same figure is obtained for both sizes. This is a strong indication that most of the loss of electrode is due to burning, both of the sides and of the tip of the electrodes, rather than to electrical phenomena occurring at the point on the electrode where the arc strikes. If this is so, the increased rate of wear with increased power input must be due to the electrodes reaching a higher temperature and/or to an increased air circulation within the furnace. The effect of power input is slightly less marked with the 7-in. electrodes than with the 4-in., which is to be expected since a given increase in power should produce a lower rise in temperature in the electrodes of greater cross-section.

These results are of great interest, but no final conclusions on the effect of power input can yet be drawn, since it is clear that the whole subject of electrode consumption needs further study, particularly with respect to the more exact distribution of electrode wear between tip and sides, and the effects of voltage, current, and current density.

### Electrode Breakage

Losses of electrode by breakage in the three trials referred to above were as follows (breakage during removal or replacement of the electrodes being excluded):

(i) Trial 4 (4-in. electrodes): one breakage of 6 lb in the 24 heats, giving a loss of 0·5 lb/ton
(ii) Trial 5: no breakage
(iii) Trial 6: one breakage of a 4-in. electrode in the 24 heats using this size; the weight was not recorded. A loss of, say, one-third of a length (i.e. 9 lb) would be equivalent to about 0·8 lb/ton. No breakage of the 7-in. electrodes occurred.

Some further breakage losses of electrode or

**Table XIII**
**ELECTRODE CONSUMPTION IN TRIAL 6, lb/h**

| | 4-in. Electrodes | 7-in. Electrodes |
|---|---|---|
| High-power heats (538 kW) | 4·00 | 5·80 |
| Low-power heats (252 kW) | 2·03 | 3·34 |

nipple probably occurred when joints between electrodes reached the arcs, but these were too small for the pieces to be recoverable, and such losses are therefore included in the general figures for electrode consumption.

The two electrode breakages noted above occurred on low power heats. The loss by breakage is small compared with the general level in industry, but this is to be expected with the favourable type of scrap in use in these experiments. It is clear that the 4-in. electrodes are big enough for the use to which they have been put.

## ROOF TEMPERATURE

A study of roof temperature was made to assist in relating variations in roof wear to the conditions of operation with which they were associated. It is convenient to give the details here before dealing with the roof wear itself.

Initially, five thermocouples were placed at various positions in the roof so that the distribution of temperature over the inside surface could be observed. Surprisingly little variation between the readings of these thermocouples was found once a flat melt was obtained; a typical distribution of temperature just after the charge had been melted with low power input is shown in Fig. 8. In this figure the position marked *HFM* was that of a heat flow meter from whose readings (in cal/cm² s) the equivalent mean black-body temperature of the furnace could be estimated. It gave a reading comparable with that of couple 5 in Fig. 8, whose position in the furnace was also comparable. Thermocouple 5 invariably gave the highest reading of any couple and this position only was used for further roof-temperature measurements. Graphs of roof temperature at position 5 are shown in Figs. 9 and 10, Fig. 9 being at low and Fig. 10 at high power input. Power inputs are given at the tops of the graphs. The recordings showed that it was possible for the roof temperature to exceed the bath temperature, although this did not occur on all heats. It occurred only when the power remained on at a high value for too long after melting down, and the bath temperature at this time was not necessarily excessive.

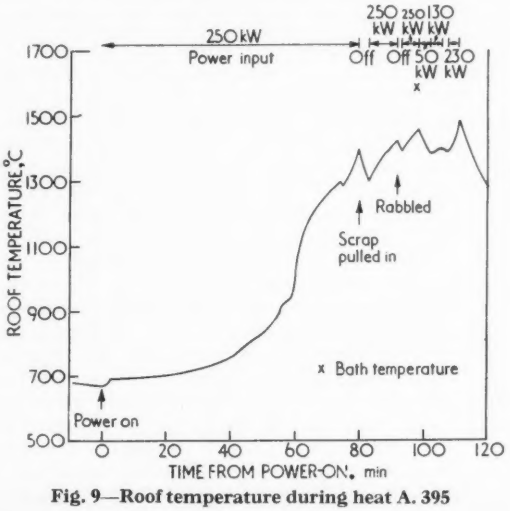


**Fig. 9—Roof temperature during heat A. 395**

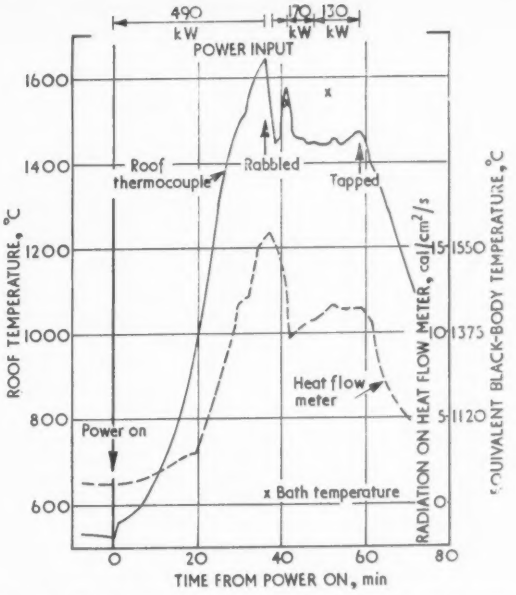


**Fig. 10—Roof temperature and heat flow during heat A. 273**

After reducing power input the roof temperature steadied out at between 100° and 200° C below the bath temperature. The heat-flow meter readings, when taken, followed a very similar course.

Subsequent work not described in this report showed that when a reducing slag was made, the roof temperature again approached, and in some circumstances could equal, the bath temperature.

Only a small increase in roof temperature occurred when the power was switched on at the start of a heat, even when using a high input. It was, therefore, unnecessary to use a lower power until the tips of the electrodes became buried in the scrap, a practice which is common on production furnaces, where the charge is often closer to the roof.

Continuous roof-temperature measurements were made in trial 6. Table XIV gives the maximum roof temperature attained in each heat and the bath temperature taken at the same time. The difference between these two temperatures is more closely related to operating conditions than is the roof temperature alone, and the average figures for this difference for each set of conditions is also given.

The difference figures show which of the conditions used are most likely to cause overheating of the roof in practice. These are (i) the low roof level, (ii) the high power input, and (iii) 7-in. electrodes. For a given bath temperature when the power input was cut down, the roof temperature was about 100° C greater with the low roof than with the high. Increase in power input and electrode size each made about 70° C difference to the roof temperature. Each of these effects was statistically significant on the 0·1% level.

The effects of roof height and power input were expected in direction although unknown in magnitude; that of electrode size was unexpected. A reason for

**Table XIV—DATA ON ROOF TEMPERATURE AND WEAR IN TRIAL 6**

| 4-in. Electrodes | | | | 7-in. Electrodes | | | |
|---|---|---|---|---|---|---|---|
| High Roof | | Low Roof | | High Roof | | Low Roof | |
| 550 kW | 250 kW | 550 kW | 250 kW | 550 kW | 250 kW | 550 kW | 250 kW |
| (*a*) Maximum Roof Temperatures of Each Heat | | | | | | | |
| 1467<br>1432 } 1448<br>1446 | 1418<br>1474 } 1412<br>1345 | 1640<br>1677 } 1662<br>1670 | 1524<br>1488 } 1522<br>1553 | 1495<br>1531 } 1513<br>– | 1605<br>1465 } 1521<br>1492 | 1685<br>1674 } 1674<br>1663 | 1545<br>1596 } 1543<br>1488 |
| 1446<br>1426<br>1450 } 1477<br>1535<br>1528 | 1439<br>1400 } 1414<br>1403 | 1625<br>1596 } 1611<br>1611 | 1456<br>1478 } 1446<br>1404 | 1553<br>1439<br>1510 } 1488<br>1449 | 1453<br>1495 } 1467<br>1453 | 1673<br>1662 } 1637<br>1575 | 1650<br>1575 } 1597<br>1567 |
| (*b*) Bath Temperature of Each Heat when Power Input Reduced | | | | | | | |
| 1635<br>1580 } 1597<br>1575 | 1590<br>1600 } 1585<br>1565 | 1590<br>1585 } 1592<br>1600 | 1615<br>1615 } 1605<br>1585 | 1565<br>1615 } 1583<br>1570 | 1575<br>1575 } 1578<br>1585 | 1580<br>1625 } 1600<br>1595 | 1615<br>1580 } 1593<br>1585 |
| 1630<br>1625<br>1565 } 1615<br>1595<br>1660 | 1620<br>1615 } 1618<br>1620 | 1670<br>1580 } 1623<br>1620 | 1590<br>1625 } 1607<br>1605 | 1615<br>1565<br>1580 } 1586<br>1585 | 1580<br>1585 } 1575<br>1560 | 1590<br>1630 } 1605<br>1595 | 1595<br>1630 } 1612<br>1610 |
| (*c*) Bath Temperature—Roof Temperature when Power Input Reduced (average figures) | | | | | | | |
| 143 | 189 | −29 | 122 | 84 | 83 | −53 | 32 |
| All high-power 36° C<br>All high-roof 125° C<br>All 4-in. electrodes 106° C | | | | All low-power 107° C<br>All low-roof 18° C<br>All 7-in. electrodes 37° C | | | |
| (*d*) Roof Wear, lb per 3 heats | | | | | | | |
| $-\frac{1}{2}$<br>−5 | +5<br>−3 | $-23\frac{1}{2}$<br>$-9\frac{1}{2}$ | $-10\frac{1}{2}$<br>$-10\frac{1}{2}$ | −11<br>− 6 | $-10\frac{1}{2}$<br>+ 1 | −28<br>$-14\frac{1}{2}$ | −11<br>−21 |
| All high-power heats 12·3 lb<br>All high-roof heats 3·8 lb<br>All 4-in. electrodes 7·2 lb | | | | All low-power heats 7·6 lb<br>All low-roof heats 16·1 lb<br>All 7-in. electrodes 12·6 lb | | | |

a small part of the difference might be a slight variation in the location of the thermocouple in the two cases, because of the difference in pitch circle diameter. However, as shown below the wear on the roof was greater with the 7-in. than with the 4-in. electrodes and this suggests a higher roof temperature overall. This may have been due to the greater pitch circle diameters used for the 7-in. electrodes, since with this greater diameter the production of heat is spread over a greater area, which would probably tend to increase the temperature of the whole of the furnace lining. A contributory cause would be the increased melting time when using 7-in. electrodes.

No account of roof temperature was taken during any of these trials in deciding when to cut down power input, only the bath temperature being considered. Such overheating of the roof as occurred could readily have been avoided, had this been desired, by reducing power input when some predetermined roof temperature had been reached.

## ROOF WEAR

The first roof wear measurements were made in trial 4 using a nearly new silica-brick roof at high level, the results being given in Table V. The measurements of roof wear, of course, include any wear during the short period between melting and tapping. It has been assumed that any such wear would be small, since the time was short and the roof temperature below the peak obtained at the end of the melting period. The figures obtained must be regarded with caution since the method of weighing in use at the time could give errors up to $\pm$ 4 lb. The increase in weight in the early heats may have been due to the absorption of iron oxide, but this does not explain the apparent gain in the final set of heats. On the whole, however, it seems probable that the true wear on the roof was greater in the high-power heats than in the low. It should be pointed out that no losses in weight by spalling occurred during this trial. Only intermittent roof-temperature measurements were made.

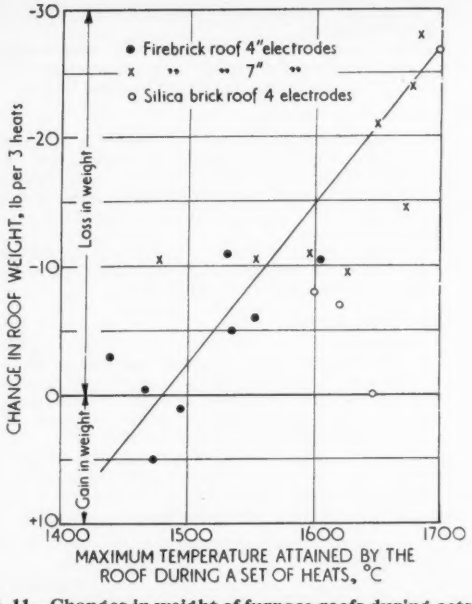


**Fig. 11—Changes in weight of furnace roofs during sets of three heats, plotted against the maximum roof temperature found during the three heats**

The same roof was used in trial 5 but at the low level. The results from the heats, which were all at high power input, are given in Table VI. A very large loss in weight occurred during the second set of three heats, probably because in one of these the bath temperature inadvertently rose to 1720° C and the roof temperature to 1700° C. This and the occurrence of some spalling in trial 5 made comparisons with trial 4 difficult. It was decided that for subsequent trials spalling would have to be avoided, since cracks in bricks formed during one set of heats might not result in loss of weight until many heats later, and the damage could easily be attributed to the wrong heats.

**Table XV**

**RADIATION AND CONVECTION LOSSES**

**(Rates of heat loss)**

| | 1st Heat Balance (3 high power heats 8V, 8A setting) | | 2nd Heat Balance (3 low power heats 5V, 5A setting) | |
|---|---|---|---|---|
| | B.t.u./h | kW | B.t.u./h | kW |
| From roof | 29,000 | 8·5 | 34,000 | 10·0 |
| From bottom | 19,000 | 5·6 | 19,800 | 5·8 |
| From door and door frame | 29,100 | 8·6 | 30,600 | 9·1 |
| From walls | 63,700 | 18·7 | 79,300 | 23·3 |
| From electrodes and holders | 2800 | 0·9 | 2700 | 0·8 |
| Totals | 143,600 | 42·3 | 166,400 | 49·0 |

In trial 6, two firebrick roofs of 36% alumina quality were used, one for 4-in. and one for 7-in. electrodes, at both high and low levels, and with two power inputs. No spalling occurred. The change in the weight of the roof varied from a gain of 5 lb to a loss of 28 lb per set of three heats, depending on the conditions of operation, the figures being given in Table VII and summarized at the foot of Table XIV.

**(i) Effect of Power Input**

Overall, roof wear was about 5 lb more per set of three heats with high power input than with low, this difference being approximately the same for high and low roof and for 4-in. and 7-in. electrodes, and representing on average about 60% greater wear. The variability between duplicate sets of heats, however, was such that the result was not statistically significant.

**(ii) Effect of Roof Height**

Roof wear was about 12 lb more per set of three heats when using the low roof level, the effect being about the same for high and low power inputs, and

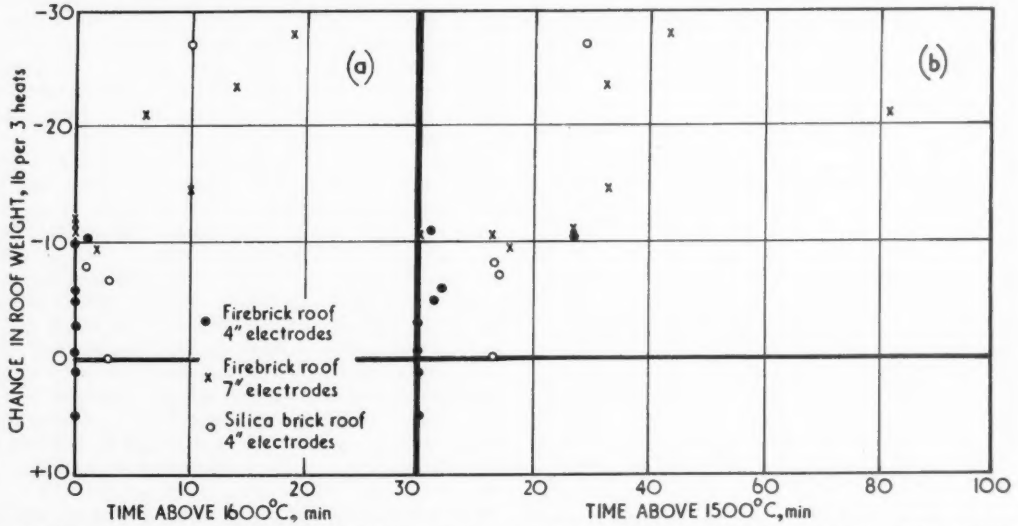


**Fig. 12—Roof wear plotted against total time roof was above (*a*) 1600° C, (*b*) 1500° C during sets of three heats**

for the 4-in. and 7-in. electrodes. Overall, the wear was about four times greater than that at the high roof level. This result was statistically significant on the 0·1% level.

**(iii) Effect of Electrode Size**

Roof wear was about 5 lb more per set of three heats with the 7-in. electrodes than with the 4-in., and this difference was independent of roof height and power input. On average this represented about 75% increase in wear, but this result was not statistically significant.

These results are adequately explained by the variations in temperature attained by the roof under the various conditions, as shown by the figures in Table XIV. The losses in weight were plotted against (*a*) the maximum temperature attained by the roof during the heats of the set, and (*b*) the average of the maximum temperatures attained in each of the heats of the set. Very similar correlations were obtained in the two cases, the former being shown in Fig. 11. The loss in weight of the roof is plotted against the total time for which the roof was above 1600° C and 1500° C during each set of heats in Fig. 12*a* and *b*. These correlations are also quite strong. Similar data for the silica roof used in trial 5 are also shown for comparison in these figures. The losses tend to be lower except perhaps at the highest temperatures.

Although the effects of power input and electrode size on roof wear were not found to be significant, statistically, it is highly probable that they are real effects since these factors were significantly related to the differences between roof and bath temperatures.

## DETERMINATION OF HEAT BALANCES

In order to obtain some appreciation of the amount and distribution of heat losses from the furnace, two sets of measurements were made when it was thoroughly warmed up during long runs. Each set was made over a period of three or four heats, so that the average heat input and heat loss for each set could be estimated.

Heat input to the system in the form of energy supplied to the transformer was obtained from the kWh meter readings. The energy usefully employed was determined from the weight of metal and slag melted and the tapping temperature. Heat losses are dealt with in the following sections.

**(i) Radiation and Convection Losses**

For the estimation of radiation and convection losses the exterior of the furnace was divided into sections such as roof, sides, door-frame, etc. The average temperature and emissivity of each section was obtained from measurements with a Land surface pyrometer,[5] and from these and their surface areas, radiation and convection losses were calculated. The results are given in Table XV in the form of average rates of heat loss over the entire period covered by the heats.

The losses in the low power heats of the second balance tend to be greater than those of the high power heats in the first because slightly higher surface temperatures were reached. This was probably due to the interval between heats being a smaller proportion of the tap to tap time for the low than for the high power heats.

**(ii) Water Cooling Losses**

Water is supplied to the roof ring, the electrode coolers, and to the door and tap-hole arches. The rates of heat loss to the cooling water were obtained by measuring the average flow and temperature rise over the tap to tap period, and were found to be equivalent to 17·4 and 19·5 kWh respectively for the first and second balances.

Separate heat losses for the various water-cooled areas have not been determined, but it is known that most of the loss is to the roof ring cooling water.

**(iii) Open Door Losses**

The average lengths of time per heat for which the door was open for various purposes were noted, and from these and the area of the opening, approximate losses by radiation were calculated, the figures obtained being equivalent to 7·5 and 6 kWh per heat respectively for the two balances.

As already indicated, losses by convection through the door have not been studied and must, therefore, be included in the unestimated losses.

**(iv) Electrical Losses**

The electrical losses were determined after calculating the various resistances and reactances in the furnace circuit, using photographic observations of the meter readings on the operating panel during normal running at high power and low power, and on short circuit tests at the respective voltage tappings. The furnace current transformers were supplemented with high grade instrument transformers for these tests and the results were calculated by assuming the furnace to be a balanced three-phase load.

**(v) Unmeasured Heat Losses and Gains and Errors of Measurement**

The principal loss not measured is that caused by the escape of hot gases from the furnace. Losses of heat to rabbles and sampling spoons are also omitted, as are heat gains or losses from chemical reactions. There may in fact be a net heat gain from exothermic reactions of 5% of the total heat input, but this is not included because of the difficulty of making an accurate assessment. In each case the unmeasured loss may be several per cent in error, since the measured losses are each subject to inaccuracies.

**Heat Balances**

Heat balances were drawn up using the data obtained on average rates of heat loss and the times taken for the series of heats. The balances are given in Table XVI, together with published data on production furnaces taken from two sources.

The low power heats required about 13% more electricity than high power heats. The percentage of energy usefully employed in the high power heats is comparable with that for the production furnaces quoted in the last two columns. In these two cases the increased heat losses caused by a longer refining period appear to be approximately counterbalanced by the increased efficiency obtainable with larger furnaces.

Heat losses from the structure in the present tests account for 17–28% of the total energy used, and are approximately proportional to the total time. As shown in Table XV more than half of this loss is from the sides and bottom of the furnace, and it seems worthwhile considering the use of insulation for these positions. If it were possible, for example, to replace the 9-in. chrome-magnesite side-walls by 6 in. of chrome-magnesite backed up by 3 in. of high temperature insulating brick the heat losses from this position would be reduced by more than 50%. If the walls above the slag line only were so replaced, total radiation and convection would be reduced by about 20%, reducing the total electricity consumption by 3–5%. The hot face temperature of the wall would be raised slightly and the possible effects on wall life would have to be considered.

**Table XVI—HEAT BALANCES**

| | B.I.S.R.A. Heat Balances | | | | Balances Made Elsewhere* | |
|---|---|---|---|---|---|---|
| | 1st Balance (High Power Heats 8V, 8A setting) | | 2nd Balance (Low Power Heats 5V, 5A setting) | | 1 | 2 |
| Weight of steel, tons | 1·5 | | 1·5 | | | |
| Total time, hours | 4·25 | | 6·97† | | | |
| Electricity used, kWh | 1062 | | 1200† | | | |
| Electricity used per ton, kWh | 708 | | 800 | | | |
| Time per ton, hours | 2·83 | | 4·65 | | | |
| | kWh/ton | % | kWh/ton | % | % | % |
| Energy theoretically required to heat steel and slag to 1600° C | 383 | 54·1 | 383 | 47·9 | 54·3 | 53 |
| Losses from structure by radiation and convection | 120 | 17·0 | 228 | 28·5 | 23·4 | 19 |
| Losses by cooling water | 49 | 6·9 | 91 | 11·4 | ... | 5 |
| Losses through door opening (radiation only for B.I.S.R.A. balances) | 15 | 2·1 | 12 | 1·5 | 3·7 | 9 |
| Electrical losses | 72 | 10·1 | 77 | 9·6 | ... | 9 |
| Losses in escaping gases / Unmeasured losses | 69 | 9·8 | 9 | 1·1 | 3·2 / 15·4 | 5 |
| Total | 708 | 100 | 800 | 100 | 100 | 100 |

* No. 1—H. J. G. Goyns, *Foundry Trades Journal*, 1953, March, p. 261
No. 2—" Anhaltzahlan für die Energieverbruch in Eisenhüttenwesen," p. 38, 1931, Dusseldorf

† The true total time and electricity consumption for this balance were 7·97 and 1285 kWh, but two of the heats were subject to delays totalling 1 h connected with the casting of the steel, and a correction based on the measured rates of heat loss has been made to make it comparable with the first balance. The effect of the delays was to increase the difference between the two balances slightly

Losses to the water are high, particularly in the second balance, compared with the production furnace results quoted. As already stated, most of the water cooling loss is in the roof ring and the method of bricking is therefore being re-examined to try to decrease the flow of heat to the ring.

The electrical losses are about the same in both heat balances; however, they would have been less on low power if the power input had been reduced to the same level by decreasing the current only rather than by reducing furnace voltage and current. This would have brought the operating point lower down the power curve on the No. 8 voltage tap (see Fig. 6) so increasing the electrical efficiency. The only disadvantage in this method of power reduction is the increased length of arc on the high voltage setting, but since during melting the arc is normally shielded by the scrap, refractory wear should not be substantially increased, providing the power input is cut down at the right time. This emphasizes the advantages that can be attained from a knowledge of the furnace electrical characteristics.

The loss of heat from the surface of the removable section of the walls was found to be approximately 10% of the total loss by radiation and convection, and thus the addition of this section would be expected to increase electricity consumption by between 1·7% and 3·0%, depending on the power input used. Such a difference could not be detected with certainty, and was not found in trial 6. A mean difference of 2% was found in trial 3.

## CONCLUSIONS FOR THE 10-cwt FURNACE

The main conclusions which can be drawn on the effects of the variables examined on electricity, electrode and roof consumptions, and roof temperature, are given below under these four headings, and are followed by a summary of the heat balance data.

### Electricity Consumption during Melting

(i) Under conditions of continuous operation (as opposed to single shift operation) about 16% less electricity is required for heats at 550 kW input than for heats at 250 kW input. The difference is slightly greater for single shift operation.

(ii) A charge material of high bulk density, such as heavy plate scrap, uses about 7% more electricity than a lighter charge nearly filling the furnace.

(iii) About 5% more electricity (per ton) is used with a 7-cwt charge than with a 10-cwt charge.

(iv) 1–2% less electricity is used with the roof in its lowest position than with the roof at the highest position. Although the average difference of 1% found in the trials was not statistically significant, it can safely be concluded from the surface loss measurements which showed a difference of about 2% that there is a true difference of this order.

(v) About 16% more electricity is required with 7-in. electrodes than with 4-in. This is partly due to the increased pitch circle diameter used with the 7-in. electrodes.

(vi) First, second, third, and fourth heats after starting with a cold furnace require approximately 53%, 12%, 6%, and 2% more electricity than heats during a continuous run.

(vii) Heats made during the second half of the life of a roof use about 5% more electricity than those in the first half. Very badly worn side walls, in conjunction with a badly worn roof, increase electricity consumption by a greater amount, an increase of 17%

over that found with new walls and roof being obtained for the case considered.

**Electrode Consumption**

(i) Power input has little effect on electrode consumption measured as lb/ton of steel but the consumption per hour is much greater at high power input. This effect is somewhat less with the 7-in. electrodes than with the 4-in.

(ii) About 20% less electrode is consumed with the roof at the low level. The proportions are the same as those of surface area of electrode exposed within the furnace.

(iii) The consumption of the 7-in. electrodes per ton of steel is nearly twice that of the 4-in. and is almost exactly in proportion to the area of surface of electrode exposed in the furnace; thus consumption per ton of steel per ft² exposed is the same for each size.

**Roof Temperature**

(i) The highest roof temperature is obtained just before reducing the power input after melting. Under some conditions the roof temperature at this time can be above the bath temperature.

(ii) For a given bath temperature at the time of reducing the power input, the roof temperature is on average 70° C greater with high power input (550 kW) melting than with low (250 kW).

(iii) For a given bath temperature at the time of reducing the power input, the roof temperature is on average 100° C greater with the low roof than with the high.

(iv) For a given bath temperature at the time of reducing the power input, the roof temperature is on average 70° C greater when using 7-in. electrodes than when using 4-in. This may be partly or wholly due to the larger pitch circle diameter used with the 7-in. electrodes.

**Roof Wear**

With a firebrick roof:

(i) Roof wear is clearly related to roof temperature, increasing as the maximum temperature attained by the roof increases.

(ii) Low roof level, high power input, and the use of the larger electrodes increase roof wear, the first of these having the greatest effect, and increasing the average wear to about 4 times that found at high roof level, i.e. by about 12 lb per set of three heats. The apparent effect of the larger electrodes may again be largely due to the increased pitch circle diameter used.

Because of spalling, the data on silica roofs were insufficient for any definite conclusion to be drawn, although it seems likely that here also the factors which increase roof temperature will increase roof wear.

**Heat Balances**

Heat balances for high and low power heats, covering melting, a short holding period, and the normal interval between heats, indicate that approximately 54% and 48% respectively of the electricity consumed is needed for the essential task of heating the steel and slag to the required temperature.

The major losses are by: (i) radiation and convection from the structure, (ii) to the cooling water, and (iii) electrically.

Losses (i) and (ii) are much greater with the low power input, but the electrical loss is about the same for high power and low power inputs. A reduction in radiation and convection losses by the replacement of part of the side wall lining by insulating brick is possible and may be practicable, although the effect of this on the life of the lining needs to be ascertained by trial. Water cooling losses can probably be reduced by modifications to the roof bricking. Electrical losses on low power can be reduced by operating at a higher voltage and lower current.

## APPLICATION OF RESULTS TO PRODUCTION FURNACES

In this section the possibility of the application of the conclusions which can be drawn from this work to production furnaces is discussed, together with the results likely to be obtained. Application should be possible partly on existing plant and partly only on new installations.

**Power Input During Melting**

*Effect on Electricity Consumption*

As on the 10-cwt furnace, the use on production furnaces of the highest power input setting should result in the lowest electricity consumption in melting, providing the optimum current is not exceeded. The reason for the lower electricity consumption is the decreased melting time with the consequent reduction in heat lost. Since with larger furnaces the losses are a smaller proportion of the heat input, less saving by decreasing the melting time is possible on a large furnace than on a small one. This must be allowed for in applying the results on the 10-cwt furnace to production furnaces. From the electricity consumption in melting down on a number of production furnaces, it is estimated that the possible savings on 10–20 ton furnaces by decreases in melting time will be about 60% of those on the 10-cwt furnace.

The use of the highest power input will not always result in the lowest electricity costs, because of maximum demand charges. The incidence of maximum demand charges varies greatly under different circumstances, depending on the amount of demand from other electricity consuming equipment connected to the same maximum demand meters. In cases where the maximum demand of the furnace determines the maximum to be paid, and the full demand occasioned by the furnace is charged against the furnace, this accounts for 25–40% of the total electricity costs for the furnace (that is for a furnace working on a 3-shift basis), the other 75–60% being the cost of the units consumed. For furnaces operated in conjunction with other electrical equipment imposing a heavy demand, or for two furnaces operating together with melting periods staggered to avoid overlapping, maximum demand charges bear less heavily.

The effects of power input during melting on these charges and on production rate are best considered in examples. In the examples taken the following assumptions are made:

Charge weight 20 tons
Highest power input (i.e. on the highest voltage tap and maximum current setting) 4500 kW at 0·78 power factor
Electricity consumed in melting at the highest power input 520 kWh/ton
Refining time 3·25 h. Power input during refining 1500 kW at 0·96 power factor
Fettling and charging time 0·50 h
Unit cost of electricity 0·65*d.*/kWh
Maximum demand charge £3 15*s.* 0*d.*/kVA per year
Furnace operating a 128-hour week, 45 weeks per year
Yield of sound ingots, 90%
Increase in tap-to-tap time due to staggering of melting periods of two furnaces, 5%

The increases in electricity consumption with power

input below the highest are assumed to be 60% of those shown in Fig. 4. The electricity costs for operation at the highest power input and for 20% and 40% lower inputs are analysed in Table XVII for a single furnace, and for two furnaces operating with staggered melting periods. Because of the smaller heat losses with a 20-ton furnace, the increases in time required with the two lower inputs are slightly less than those given by Fig. 4 (28% and 78% respectively instead of 30% and 85%). From Table XVII it is clear that, when the furnace demand determines the maximum demand charges, as the power input to the furnace is increased to a maximum the increasing demand charge can more than offset the reduction in units charge. In the example shown, the reduction of 20% from the highest input results in a saving in electricity costs of about 5*s.* per ton, but a further reduction of 20% only reduces the total electricity costs by another 1*s.* 6*d.* per ton. However, assuming full utilization of the furnace, output would be reduced by 10% and 23% respectively in these two cases, and in general this would more than counteract the advantage of any reduction in electricity costs.

For two furnaces working with staggered melting periods and creating the full maximum demand, the total electricity costs are only slightly affected by power input within the range given, but reductions in power input below the highest level again reduce production by the same percentages. Where the furnace is not charged on maximum demand, the cost of electricity is clearly least when the power input is greatest.

### Table XVII

**ANALYSIS OF ELECTRICITY COSTS AT THREE INPUT RATES DURING MELTING**

| | At Highest Input | 20% below Highest Input | 40% below Highest Input |
|---|---|---|---|
| Power input in melting, kW | 4500 | 3600 | 2700 |
| Average power factor during melting | 0·78 | 0·90 | 0·94 |
| Melting time, h | 2·31 | 2·96 | 4·11 |
| Electricity consumption in melting, kWh/ton | 520 | 532 | 555 |
| Electricity consumption in refining, kWh/ton | 244 | 244 | 244 |
| Cost of units for melting, per ton | £1 8 2 | £1 8 10 | £1 10 1 |
| Cost of units for refining, per ton | £0 13 3 | £0 13 3 | £0 13 3 |
| Total cost of units, per ton | £2 1 5 | £2 2 1 | £2 3 4 |
| **For a single furnace** | | | |
| Maximum demand, kVA | 5770 | 4000 | 2870 |
| Tap-to-tap time, h | 6·06 | 6·71 | 7·86 |
| Average no. of heats per week | 21·1 | 19·1 | 16·3 |
| Maximum demand cost, per ton | £1 2 10 | £0 17 5 | £0 14 8 |
| Total electricity cost, per ton | £3 4 3 | £2 19 6 | £2 18 0 |
| Production rate, tons good ingots per h | 2·97 | 2·68 | 2·29 |
| **For two furnaces with staggered melting periods** | | | |
| Maximum demand, kVA | 7330 | 5560 | 4430 |
| Tap-to-tap time, h | 6·36 | 7·05 | 8·25 |
| Average no. of heats per furnace per week | 20·1 | 18·2 | 15·5 |
| Maximum demand cost, per ton | £0 15 2 | £0 12 9 | £0 11 11 |
| Total electricity cost, per ton | £2 16 7 | £2 14 10 | £2 15 3 |
| Production rate per furnace, tons good ingots per h | 2·83 | 2·55 | 2·18 |

*Effect on Electrode Consumption*

On the 10-cwt furnace wide variations in power input had little effect on electrode consumption per ton of steel and it seems likely that the same will be true for production furnaces, provided the current density does not exceed a maximum figure. This maximum depends on electrode size, but from the electrode makers' data and the results on the 10-cwt furnace it is probably considerably higher than the maximum current density at present used on most production furnaces.

*Effect on Roof Wear*

Higher roof temperatures and greater roof wear were found on the 10-cwt furnace with the higher power inputs, particularly with the roof at the low level. The ratios of diameter inside the brickwork to height from sill to roof ring for the 10-cwt furnace at the high and low roof levels were 1·6 and 2·5 respectively. The ratio for the low roof level is the more comparable with that for most production furnaces as will be seen from the fact that for furnaces described in the 1949 report,[3] this ratio averaged 2·1 for furnaces of up to 7 tons capacity, and 3·1 for those above this capacity. The modern trend, however, is towards increasing roof height. The increased roof temperature and roof wear on the 10-cwt furnace could readily have been avoided by reducing the power input when a predetermined roof temperature, say 1550° C, had been reached. This temperature was reached only very shortly before the bath reached 1600° C, and the increase in the time required to reach 1600° C caused by reducing power input would not have been great.

It seems likely that increased roof wear on production furnaces, using higher power inputs, could be avoided in a similar manner by reducing power input at the appropriate time. This time should preferably be determined by actual roof temperature measurement, which in practice will probably have to await the development of thermocouple sheaths having a longer life under these conditions. In the absence of roof temperature measurement power input might be cut at a fixed interval after power-on, allowing a sufficient safety margin.

Although on the 10-cwt furnace it was possible to use a high power input right from the start of a heat without damage to the roof, this may not be possible on top charged furnaces where the scrap is sometimes almost touching the roof. The normal practice of using a lower input until the electrode tips have penetrated a short distance into the scrap would then have to be followed.

The possibility of damage to the furnace walls when using high power input has also to be considered. In some cases this will be more serious than damage to the roof. It might, however, be possible to guard against it by the use of a thermocouple in a recess in the wall in a suitable position, and this possibility is being examined.

*Summary*

Since no increase in electrode consumption occurs with increased power inputs, and it appears possible to avoid increased roof wear, the economies of using existing furnace transformers to their maximum capacity depend on (*a*) maximum demand charges, and (*b*) the value of a high production rate. The latter may well be the over-riding consideration. For new installations the data obtained in this work may be of use in helping to determine transformer size, and in determining the relative dimensions of the furnace.

**Variation in Roof Height**

Roof height on production furnaces is partly determined by the nature of the scrap which has to be charged. The importance of reducing back-charging to a minimum is generally recognized although it is still frequently necessary. This argument favours a high roof level, and is often the over-riding consideration.

The effect of roof height on roof wear found under the conditions of the trials with the 10-cwt furnace would probably not be as pronounced on production furnaces operating a two-slag process, since it was noted that with reducing slags, roof temperature could rise to equal the bath temperature even with the low power input required during refining. Even under these conditions, however, a high roof should be advantageous if wear is reduced during the melting period alone.

The advantage of a low roof level in giving a low electrode consumption may only apply to cases where the scrap used is of such a type that the whole of it can be charged at once, even with the low roof level. If a high roof is necessary to accommodate the whole charge, this will probably be preferable to the use of a low roof, with subsequent back-charging and the resulting increase in melting time. The results from the 10-cwt furnace were obtained for the melting period, plus a short period only under an oxidizing slag but from subsequent incomplete work it is clear that the relationship of electrode wear to area of surface exposed also applies during the refining period. Thus once the charge is melted, a low roof level is the best from the point of view of electrode wear. The ability to reduce or eliminate back-charging is, however, probably the more important consideration.

**Variation in Electrode Size**

The comparative difference in size between the 4-in. and 7-in. electrodes used on the 10-cwt furnace is much greater than any difference between two sizes that could be compared on a production furnace, and the effects of possible variations on such furnaces are, therefore, less. A typical comparison is between 12-in. and 14-in. electrodes. It seems likely that the relationship found between surface area and consumption will apply, so that the electrode consumption with 14-in. electrodes will be about 15% greater than that with 12-in. This assumes that the current density with the smaller size electrodes is not excessive and that electrode breakage with either size accounts for only a minor proportion of the total electrode consumption. Electrodes should clearly be large enough for this to be so, the size required depending to a certain extent on the nature of the scrap to be melted.

Although in the 10-cwt furnace losses by breakage occurring when the joints in the electrodes reach the arcs are usually too small to be important, such losses are often more serious on production furnaces. The effect of electrode diameter on the liability to such losses is difficult to predict.

The difference of 16% in electricity consumption in melting found on the 10-cwt furnace when comparing the 4-in. with the 7-in. electrodes was partly due to the accompanying difference in pitch circle diameter. Only about 4% of this difference could satisfactorily be explained by the difference in size. The change in size from 14 in. to 12 in. suggested above is proportionately much smaller; and would probably have little effect on electricity consumption in melting unless accompanied by a change in pitch circle diameter.

The effects of the larger electrode size on roof temperature and wear in the 10-cwt furnace have not been fully explained although they too are probably related to the pitch circle diameter. The effects of a change in electrode size on roof wear in a production furnace cannot, therefore, be predicted.

**Heat Balances**

The results obtained on the 10-cwt furnace cannot be directly applied to production furnaces, but the possibilities for reducing heat loss appear to be such that the making of similar balances on further production furnaces should be worth while. For example, the saving of 3–5% in electricity consumption calculated for the 10-cwt furnace by the replacement of the 9-in. chrome-magnesite walls above the slag line by 6 in. of chrome-magnesite and 3 in. of high-temperature insulating brick would be almost equalled on a furnace with 14-in. chrome-magnesite walls if these were replaced by 11 in. of chrome-magnesite and 3 in. of high-temperature insulating brick. Such a change would probably tend to reduce the life of the walls, but it is not known how serious this effect would be. The possibility of reducing water-cooling losses may also be worth considering.

Electrical losses on production furnaces might be reduced if the furnace electrical characteristics were known and fully utilized in the operation of the furnace. Another item which is important in the efficient operation of the furnace where a supplementary reactor is included in the furnace installation is the correct adjustment of supplementary reactance in circuit on each voltage tapping.

## GENERAL CONCLUSIONS

The work described has shown that the operation of the 10-cwt arc furnace gives results sufficiently consistent for conclusions to be reached on the effects of certain variables. The most important conclusions are tabulated below, with the authors' views on their applicability to production furnaces.

**Electricity Consumption**

| *Conclusions for 10-cwt furnace* | *Applicability to production furnaces* |
|---|---|
| The following favour a low electricity consumption:— | |
| (i) High power input during melting<br>The use of high power input has the important advantage that melting time is kept short | Applicable, though with a somewhat smaller effect |
| (ii) Low roof level (only a small effect) | Rarely applicable |
| (iii) Charges which fill the furnace space | This is generally the case |
| (iv) Operating at full charge capacity | Applicable, i.e. the current practice, which is to overcharge, tends to reduce the electricity consumption per ton |
| (v) Continuous operation | Applicable, though with a smaller effect |
| The use of smaller electrodes also probably reduces electricity consumption but this point cannot be regarded as proved even for the 10-cwt furnace since in the experiments the pitch circle diameter was varied at the same time as the electrode size | Probably only a very small effect |
| The application of insulation to the side walls of furnaces could in theory result in electricity savings of up to 5%, but the effects of this on wall life have not yet been studied, even on the 10-cwt furnace | Not advisable before trials on the 10-cwt furnace have been made |

**Electrode Consumption**

| *Conclusions for 10-cwt furnace* | *Applicability to production furnaces* |
|---|---|
| The following favour a low electrode consumption:— | |
| (i) Small electrodes; consumption is approximately proportional to electrode diameter, provided the current density is not excessive and the electrode is large enough to avoid appreciable breakage | Applicable |
| (ii) Low roof level; consumption is proportional to the height of the roof above the bath | May only be advantageous when the use of low roof level does not necessitate the introduction of or an increase in the amount of back-charging, thus increasing melting time |

**Roof Wear**

| *Conclusions for 10-cwt furnace* | *Applicability to production furnaces* |
|---|---|
| The following favour low roof wear: | |
| (i) High roof level | Applicable |
| (ii) Low power input in melting. High power input is only detrimental when precautions are not taken to reduce the power input at the appropriate time | Applicable. The detrimental effect of high power input should be overcome when continuous roof temperature measurement has been developed for routine use.<br>Production rate may be the overriding factor. |

A full study of the electrical characteristics of existing installations should be made to determine the optimum operating conditions.

## FUTURE WORK

This report covers most of the work planned for the 10-cwt furnace on the economic aspects of electric furnace operation. Work in hand or yet to be started includes the following:

(i) Study of the distribution of electrode wear between the tip and the sides of the electrode, and the extension of electrode wear studies to the refining period
(ii) Investigation of means of reducing electrode wear by the prevention of oxidation
(iii) More detailed and exact study of the electrical characteristics of the installation
(iv) Attempts to improve roof temperature measurement.

Work on the 10-cwt furnace on the metallurgical and chemical aspects of the steelmaking process will initially be on the removal of sulphur and phosphorus. A start will be made by applying existing formulæ obtained from laboratory work to the arc furnace slags to determine to what extent equilibrium with the metal is obtained. Other work may be on grain refinement and steel cleanliness. The possibility of utilizing the small d.c. e.m.f. produced between the furnace hearth and the star point of the furnace transformer, to give information on slag and metal conditions, will also be studied.

It is intended to make tests on production furnaces wherever possible in order to confirm the results obtained on the 10-cwt furnace.

## Acknowledgments

The authors are greatly indebted to Dr. A. H. Leckie, Dr. J. Pearson, and Mr. R. Mayorcas, and to the members of the Electric Process Sub-Committee, for guidance and for many useful discussions during the course of the work; to Mr. L. Norris who was responsible for many of the heats and to Messrs. P. Hobson, H. Leaper and H. Hargreaves and the other members of the staff of B.I.S.R.A. who took part in the trials or assisted in other ways.

The valuable help given by Messrs. Stewarts and Lloyds Ltd., Corby, and by Mr. R. V. Thomas of that Company, in the supply of tube scrap is gratefully acknowledged, as is the help given by the Appleby-Frodingham Steel Company in the supply of the heavy plate scrap used in one trial.

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# Applications of the Electron Probe Microanalyser

*By J. Philibert and C. Crussard*

SYNOPSIS

The Castaing-ONERA Electron Probe Microanalyser has been in service for a short time at IRSID. The instrument permits elementary point analyses to be made (over an area of 1–2$\mu$ dia.) of all elements of atomic number greater than 17, with an error of 1%. The results of the first experiments made at IRSID to explore its possibilities for ferrous metallurgical investigation are reported, from the study of ores (oolite), oxide scales, and segregation bands in steels, to metallographical studies (phase transformations, analysis and identification of phases, and studies of diffusion). 1292

THE MICROANALYSER with electronic probe invented by R. Castaing and constructed by the Office Nationale d'Etude et Recherches Aéronautiques is intended for making quantitative elementary analyses at points in massive specimens, metallic or otherwise (*see* Fig. 1). The apparatus itself has been described elsewhere[1]; the principle is, briefly, that an extremely fine pencil of electrons (the electron probe) is directed at the specimen and the characteristic X-rays emitted by the specimen under the impact of the electrons are analysed. The apparatus therefore consists essentially of an electron optical system and an X-ray spectrometer; a mirror-objective microscope permits normal observations of the specimen, prepared as usual for metallography, to be made.

The extent of the ' resolving power ' of the apparatus is 2$\mu$ in length (this being the minimum diameter of the region analysed) and 1–2$\mu$ in depth. All elements heavier than chlorine (atomic No. 17) can be determined, and the extension to elements down to aluminium or magnesium is being studied. However, the analysis of very light elements like carbon, nitrogen, and oxygen is not at present envisaged.

The error in analysis is about $\pm 1\%$ for elements in concentrations greater than 0·5%, which excludes analysis of traces (concentrations below 0·1%).

The present paper gives the results of tests made since the microanalyser has been in service at IRSID. These experiments were made mainly to assess rapidly the scope of the apparatus in the various branches of metallurgical research, namely, the study of ores (distribution of iron in oolites), of oxide scales in mild steel (selective oxidation), and of minor segregation of Ni, Cr, and Mn in steels having a banded structure. The paper continues with results obtained in phase-transformation studies: the identification of precipitates (oxides, carbides, sulphides, etc.) and the analysis of different constituents—measurements from which it is easy to work out constitutional diagrams. The paper ends with a report of some studies on diffusion in various metals and alloys.

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Professor Crussard is Head of the Department of Physics of the Institut de Recherches de la Sidérurgie and Dr. Philibert is a member of the staff.

## STUDY OF IRON ORES

The microanalyser can be used for the study not only of metals but also of insulators by a special surface treatment (metallization of the surface to a thickness of 300 or 400 Å). Examination has been made of oolites extracted from Lorraine ore (Sainte-Barbe brown ore), enveloped in plastic, and polished (*see* Fig. 2). Determinations of iron have been made in the core and in the various concentric aureoles of the oolite. Table I gives some typical results.

**Table I**

**EXAMINATION OF OOLITIC ORE**

| Oolite No. | Part Analysed | Fe, % |
|---|---|---|
| 1 | Central core | 50·5 |
| | Very black zones | 43·5–44·5 |
| | White zones | 48·5–49·5 |
| | Grey zones | 45·5–46·5 |
| 2 (Fig. 2) | Central core | 52·5 |
| | Very black zones | 42·5 |
| | Grey-black zones | 45·5–46·5 |
| | White zones | 48–49 |

**Note: The manganese concentration is too low for a detailed study but it seems that the zones richest in iron are always richest in manganese.**

**Fig. 1—Electron probe microanalyser**

The usual approximation is not accurate enough for determining the contents of ores from measurements of line intensities. If $k_A$ is the intensity ratio for a strong line ($K\alpha_1$ in the present case), emitted by an element $A$ in the 'alloy' studied and by the pure element (standard or reference specimen), to a first approximation

$$C_A = k_A \ (C_A = \text{concentration of } A) \quad \ldots\ldots\ldots (1)$$

Castaing[1] has shown that a second approximation is

$$C_A = \frac{k_A}{(1 - a)k_A + a} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

where $a$ is a coefficient which is a function of the different absorption effects for electrons of the various elements of the alloy.

For alloys of elements of neighbouring atomic numbers, $a$ can be taken as unity and equation (2) reduces to equation (1). In the present case, where the alloy contains about 50% of light elements (oxygen in particular), equation (2), which is hyperbolic, must be used. But $a$ cannot be worked out as a function of the Lenard coefficients for the elements in the 'alloy'; it is simplest to determine it empirically. To do this, samples of hematite have been prepared in the same way as the oolites; under these conditions for an iron concentration of 0·70, it is found that $k_{Fe} = 0{\cdot}65$, and $a$ is deduced to be about 0·80. This is the value of $a$ with which the values in Table I for the iron concentration have been calculated, via equation (2).

It is intended to confirm this value of $a$ with other specific compounds having various iron contents, e.g. goethite and siderite, and to see if an identical value of $a$ is obtained from pyrites.

## SELECTIVE OXIDATION DURING THE FORMATION OF SCALES

Billets reheated in an oil-fired furnace exhibit surface oxide scales of complex structure, the various constituents of which can be investigated in a micrographic section with the microanalyser. In particular studies have been made of billets of O.H. medium-hard steel of composition: C 0·4%, Mn 0·6%, Si 0·31%, Ni 0·22%, and Cu 0·14%. The micrograph of the internal part of this scale (Fig. 3) shows the existence of four phases. The results of the analyses given in Table II enable the phases to be identified from their content of Fe (+ Mn), since it is known almost in advance what phases will be encountered.

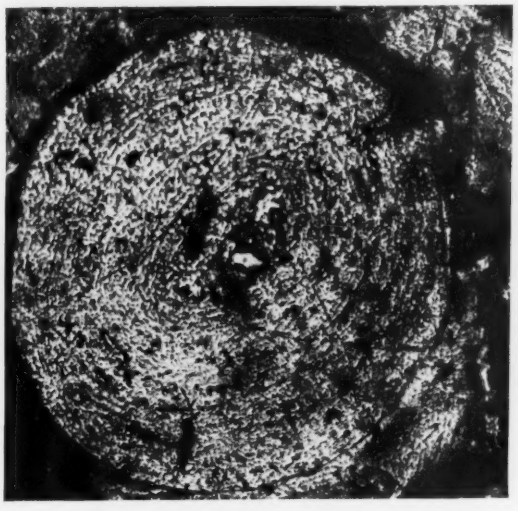
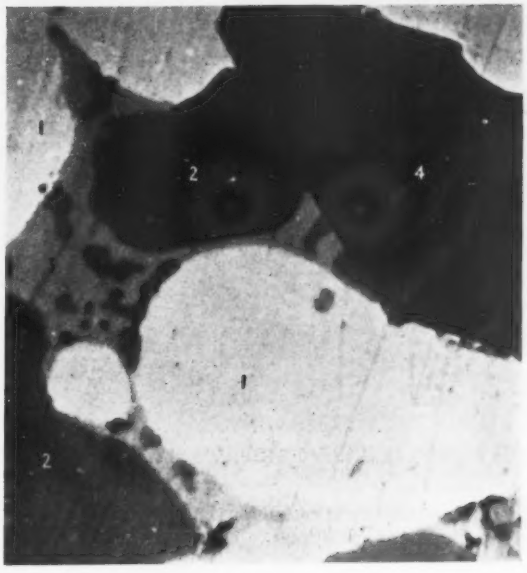


**Fig. 2—Mechanically polished oolite extracted from a Sainte-Barbe ore** × 180




1: Metal; 2: FeO; 3: FeS; 4: Silicate

**Fig. 3—Mechanically polished oxide scale in O.H. steel** × 1200

There is a considerable enrichment in Ni of the metal present as a core surrounded by oxides, sulphides, and silicates, in which no trace of this metal could be detected. In the same way, there is segregation of Cu, which also appears in the sulphide, but is not detectable in the oxide or silicate. Conversely, manganese appears mainly in the silicate.

## SEGREGATION OF Cr, Ni, AND Mn

In steels having a marked banded structure, a minor segregation has been detected, fairly low for Cr and Ni in an Ni–Cr–Mo steel, but much stronger for Mn in a tyre steel.

### Segregation of Ni and Cr

The steel investigated was of the following percentage composition:

| C | Mn | Si | S | P |
|---|---|---|---|---|
| 0·16 | 0·46 | 0·2 | 0·013 | 0·008 |
| **Ni** | **Cr** | **Mo** | **Cu** | **As** |
| 3·02 | 1·02 | 0·26 | 0·12 | 0·055 |

This steel exhibits well-marked segregation bands after tempering at 850° C for 30 min. It was studied after tempering for 28 h at 600° C; there is an alternation of ferritic and pearlitic zones after etching with nital (Fig. 4). The contents of Ni and Cr in these zones are given in Table III.

The variations of nickel are quite low: not more than 20% in relative value. The variations in chromium content are also small, and hardly more

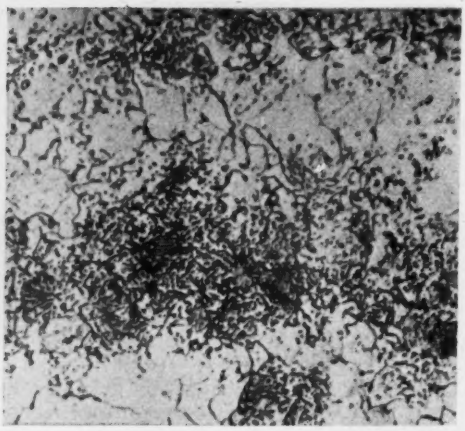


**Fig. 4– Steel 16*NCD*13, austenitized at 850° C and tempered for 28 h at 600° C. Etched with nital × 540**

than the concentration heterogeneity on the scale studied. These variations can always be revealed by making analyses with the electron probe at various points across two adjacent bands.

**Segregation of Manganese**

An apparently considerable segregation of manganese in hot-worked steels has already been revealed by microradiography[2]; this segregation more or less follows the fibre texture. But the resolving power of microradiography is not high enough to indicate whether the manganese in question is present as (sulphide ?) inclusions and gives no idea of the magnitude of the segregation. These questions can be answered with the microanalyser. A tyre steel containing 0·55% C, 1·05% Mn, 0·026% S, 0·3% Si, 0·020% P was studied. Etching with Comstock's reagent (*see* Fig. 5), which reveals phosphorus segregation (the black zones are low in phosphorus), produces a typical segregation-band pattern. Some sulphides may be observed in the white bands. The results of analyses of Mn and Fe at different points are shown in Table IV.

These analyses show that, independently of segregation of manganese due to the presence of sulphides,

**Table II**
**EXAMINATION OF MILD-STEEL SCALES**

| Area Analysed | Fe | Mn | Ni | Cu | Total Metal | Phase |
|---|---|---|---|---|---|---|
| 1: white | 96 | 0 | 3 | 0·75 | 100 | Metal |
| 2: mouse grey | 77 | 0·5 | Nil | Nil | 77–77·5 | FeO |
| 3: yellow-grey | 62 | 0·5 | Nil | 0·8 | 63–63·5 | FeS |
| 4: grey-black | 52 | 1–1·5 | Nil | Nil | 53 | Silicate |

**Table III**
**ANALYSIS OF Ni–Cr–Mo STEEL**

| Zone Analysed | Ni, % | Cr, % |
|---|---|---|
| White | 2·70–2·80 | 0·8–0·9 |
| Grey | 2·9–3·1 | 1 |
| Grey-white | 3·2 | 1·2 |

**Table IV**
**Mn AND Fe ANALYSES**

| Zone Studied | White | Grey | Black | Sulphide |
|---|---|---|---|---|
| Mn, % | 1·4 | 0·9–1·1 | 0·7 | 42·5 |
| Fe, % | | | | 20·5 |

there is a considerable segregation in the body of the metal itself, in the same zones as those in which phosphorus segregates. A subject for further study is whether this segregation is simultaneous or whether one controls the other.

**TRANSFORMATIONS IN STEELS—IDENTIFICATION AND STUDY OF CONSTITUTION DIAGRAMS**

It has already been seen, from the study of billet scales, that the microanalyser can be used to identify compounds of stoichiometric composition. Later examples are given of similar identifications of sulphides, carbides, etc. Local analysis of two phases present in equilibrium enables constitution diagrams to be worked out with a much smaller number of alloys than do the customary methods.

**Sulphides**

Local analyses were made on two types of sulphides found in casting skins on cast iron (Fig. 6): the yellowish-grey hexagonal ' iron sulphide ' and the mouse-grey cubic ' manganese sulphide.' The results are given in Table V; the total Fe + Mn is always 63%, which corresponds satisfactorily with the stoichiometric composition of the sulphide and at the same time identifies it.

Note that the iron sulphide scarcely dissolves any manganese, while the ' manganese sulphide ' sometimes contains more iron than manganese.

**Carbides**

In high-alloy steels, the microprobe allows the

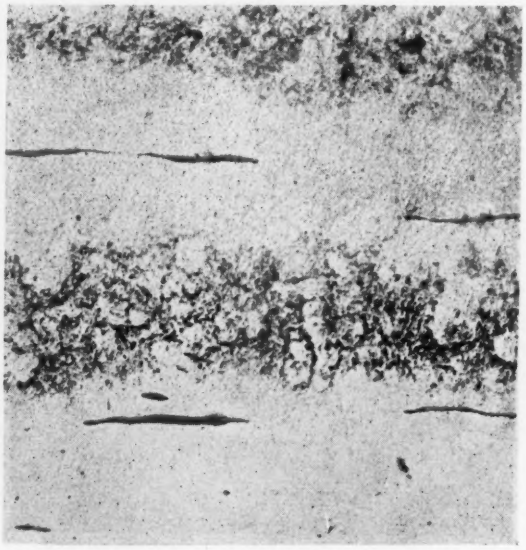


**Fig. 5—Strip steel containing 1% Mn, etched with Constock's reagent × 350**

**Table V**

**ANALYSES OF SULPHIDES ON CAST IRON**

| Zone Analysed | Mn | Fe | Total |
|---|---|---|---|
| Yellowish-grey | 2–3 | 60–61 | 63 |
| Mouse-grey | 43 | 20 | 63 |
| ,, | 36 | 27 | 63 |
| ,, | 25·5 | 37·5 | 63 |

evolution of carbides to be followed during high-temperature heat-treatment. Specimens were analysed that were provided by J. Papier[3] and had been used by him in a study of 18–4–2 high-speed steels. The composition of this alloy was C 0·8%, W 18·8%, Cr 4·4%, V 1·9%.

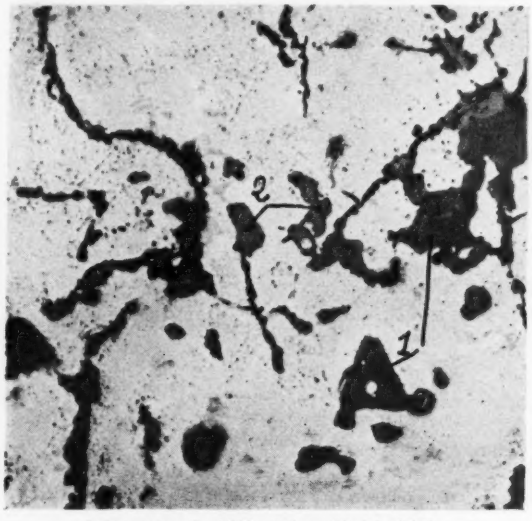
An interesting point is that in this case the micro-analyser can be used for direct analysis of the matrix while in the ordinary method involving electrolytic extraction of carbides, the composition of the matrix is determined by difference.

The specimens were studied after annealing at 1300° and 1050° C; after the first treatment, the carbide particles were fairly large (5μ approx.), while in the second case their dimensions were at the limit of the resolving power of the instrument. Table VI presents the proportions of Fe, W, and Cr in the complex tungsten carbides and the matrix; no figures are available for vanadium carbides and this should be the subject of further investigation.

In an Ni–Cr–Co turbine-blade austenitic steel, containing in addition a few per cent of Mo, W, and Nb, micrographs revealed minute grains of precipitated carbide; analysis reveals that these carbides contain only niobium, this element being absent in the matrix. It may be noted in passing that the element can be identified immediately as niobium and not tantalum.

**Segregation in an Overheated Steel**

Plateau, Duflot, and Crussard,[4] after etching a




1: ' mouse-grey ' sulphide; 2: ' grey-black ' sulphide

**Fig. 6—Sulphides formed in the skin on cast iron and mechanically polished** × 480

**Fig. 7—Hypereutectoid Cr steel, heated to 1160° C and quenched at 0° C. Austenite and ledeburite. Etched with Beaujard's reagent** × 340

hypereutectoid Cr steel overheated at 1160° C with Hall's reagent, observed coloured aureoles surrounding patches of ledeburite, indicating heterogeneity of chromium in the austenite. According to previous experiments on the diffusion of chromium in this steel, followed by etching with the same reagent, these aureoles are due to chromium enrichment. To confirm this conclusion by direct analysis, a study was made of the same steel, having the following composition: C 2·04%, Cr 2·86%, Si 0·2%, Mn 0·37%. This steel was austenitized for 6 h at 1100° C to increase the grain size, then heated for 15 min at 1160° C, and finally quenched in ice-water. After etching with Beaujard's reagent,[5] aureoles differing in colour from austenite are observed around areas of ledeburite (Fig. 7). Table VII shows the results of determination of Cr at various distances $d$ from the ledeburite.

An enrichment of chromium of about 40% relative value will be observed in a zone of 15μ. It is interesting that this rather surprising result is confirmed by the microprobe.

**Iron–Chromium Alloys**

Following Pomey's work[6] on the transformation in Fe–Cr alloys, the present authors have found that in a pure 45% Cr alloy the amounts of Fe and Cr in the α- and σ-phases (σ-phase formed by cold-working) are equal; the transformation is diffusionless.

In less pure alloys, complex carbides of iron and

**Table VI**

**ANALYSES OF TUNGSTEN CARBIDES**

| Temperature of Austenitization | Phase | Fe | W | Cr | Total |
|---|---|---|---|---|---|
| 1300° C | matrix | 84·5 | 8·5 | 5 | 98 |
| | carbide | 31·5 | 60 | 3 | 94·5 |
| 1050° C | matrix | 87·5 | 5·5 | 5 | 98 |
| | carbide | 31·5 | 56 | 3 | 90·5 |

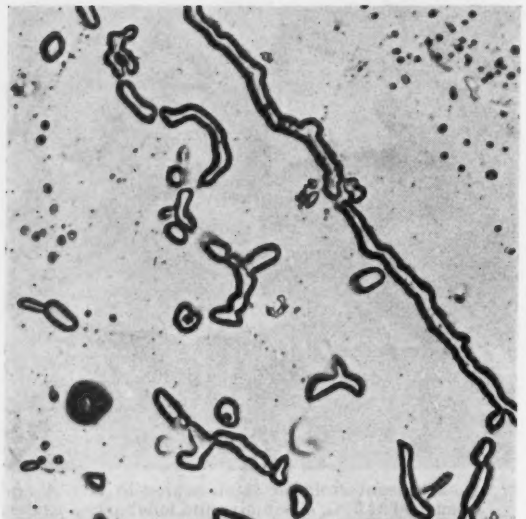


**Fig. 8—Fe–30% Cr alloy, annealed at 1050° C. Ferrite and carbides. Electro-polished** × 710

chromium can be formed by soaking at 1050° C; these carbides do not redissolve until the temperature reaches 1200° C. In a 30% Cr alloy annealed at 1050° C (Fig. 8), the parent metal is seen to be slightly depleted in Cr (28·5% Cr) and, near to the carbides, over a range of 4–5μ, the Cr content falls to 26%. Analysis reveals 59% Cr and 31% Fe in the carbides, which are therefore probably of the formula $M_7C_3$.

This example illustrates the ease with which the contents in metal elements of phases in equilibrium can be determined with the microanalyser.

## DIFFUSION PROBLEMS

The microanalyser is the best instrument for determining diffusion curves between two metals or alloys at high temperature; these curves can be plotted rapidly and with great accuracy.

A study of U–Zr interdiffusion is now being made in collaboration with the French Commissariat of Atomic Energy. At very high temperature, continuous diffusion curves are obtained, since diffusion occurs in a homogeneous phase; hence diffusion coefficients can be determined, with their concentration variations and heats of activation. At lower temperatures, there is multiphase diffusion and discontinuities on the diffusion curves enable measurements of solubilities to be made.

**Table VII**

**CHROMIUM DETERMINATION**

| | | | | | |
|---|---|---|---|---|---|
| | **Example 1** | | | | |
| ***d***, μ | **60** | **30** | **10** | **5** | **2** |
| Cr, % | **2·35** | **2·6** | **2·7** | **3·15** | **3·5** |
| | **Example 2** | | | | |
| ***d***, μ | **60** | **30** | **20** | **10** | **6** | **3** |
| Cr, % | **2·3** | **2·3** | **2·35** | **2·9** | **3·1** | **3·4** |

### Iron–Copper Diffusion

The authors have studied a series of specimens prepared by M. Sirca of the Ljubljana Institute of Metallography,* in which, during diffusion, the copper or the copper alloy used is liquid, the iron being in the form of a crucible.[7]

The diffusion zones are fairly narrow, about 10μ in certain cases, which makes it difficult to obtain precise diffusion curves. But in all cases, even when it has not been possible to obtain quantitative results such as values of diffusion coefficients, local analysis with the microanalyser has given interesting results. Three examples are given to illustrate this.

*Diffusion of Fe–Cu for* 16 *h at* 1100° *C* (*Fig.* 9)—Diffusion proceeds mainly along grain boundaries. After diffusion each grain is surrounded by a succession of differently coloured aureoles. It has been possible to prove that these do not correspond to the formation of any particular phase. After a considerable discontinuity at the Fe/Cu interface, the copper content decreases regularly and progressively from 10% to less than 0·3% at the centres of the grains. The widest diffusion bands (those most oblique to the plane of the grain boundary) do not exceed 30–40μ.

*Diffusion of Fe/Cu–P* (2%) *alloy for* 96 *h at* 950° *C*—In this case the diffusion is frontal. Three zones are observed in the iron (Fig. 10): a strongly attacked zone *A*, a zone of basaltic crystals *B*, and a zone of iron crystals of normal appearance *C*. The well-defined interfaces between these zones do not correspond to a marked discontinuity in the copper content; the variation in copper content is continuous, but the solubility of copper in iron is considerably lower than

* M. Sirca is completing at IRSID research for a thesis, begun at Ljubljana, on the interdiffusion of iron and copper in the presence of a third element. He kindly provided the authors with some of his specimens.

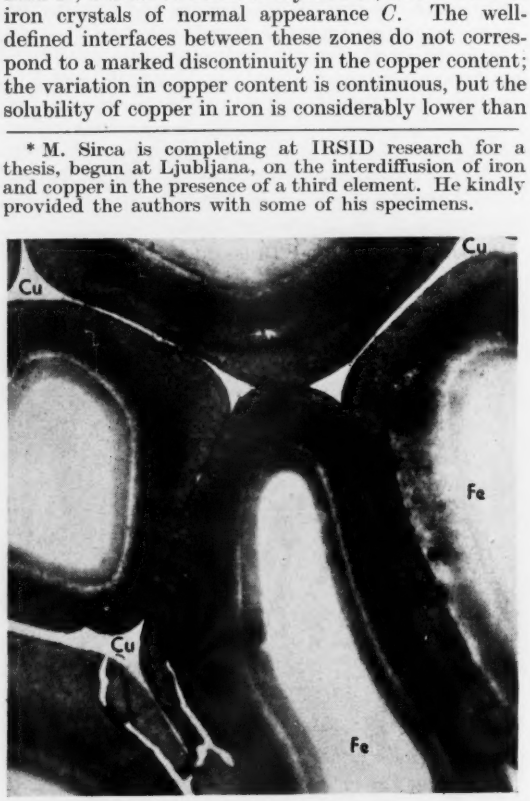



**Fig. 9—Diffusion of Cu into Fe at 1100° C for 82 h. Etched with nital. (Grain-boundary diffusion of Cu and aureoles in the Fe grains)** × 350

in the preceding case—not more than 4% of copper in zone *A*. In zone *B* a slight systematic enrichment was found across the grain boundaries. The distances, measured on either side of the boundary, are:

| $d$, $\mu$ | Cu, % Example 1 | Example 2 |
|---|---|---|
| −5 | 1·7 | 1·8 |
| | 1·8 | 1·85 |
| | 1·85 | 2 |
| +5 | 1·7 | 1·7 |

In copper, greyish-blue areas can be seen, probably consisting of a Fe–Cu–P eutectic formed on cooling; but there was depletion in Cu and enrichment in Fe in these areas as the Fe/Cu interface is approached. These distances, measured from the interface, were:

| $d$, $\mu$ | 200–300 | 100–200 | 50 | 25 | 5 |
|---|---|---|---|---|---|
| Cu, % | 1·8–2·5 | 1–1·5 | 1 | 0·6 | 0·3 |

The three last measurements are made on the same area at three points approaching the Fe/Cu interface.

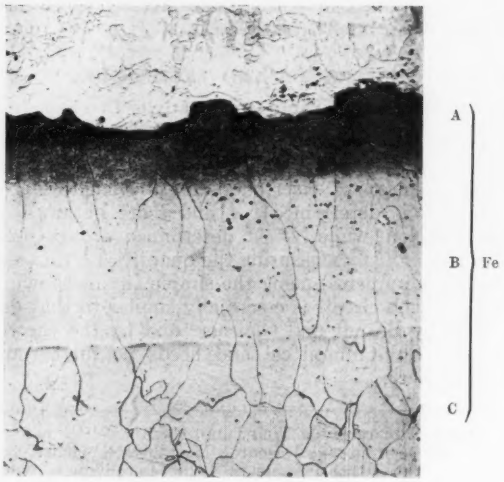
*Diffusion of Fe/Cu–Sb (2·5%) alloy for 64 h at* 1100°—In this case diffusion again occurs along grain boundaries. In each grain aureoles concentric with the boundaries are observed. In particular, there is a blue aureole (*see* Fig. 11). It was not possible to determine Sb contents, but only those of Fe and Cu.

Progressive segregation of Cu is observed as the grain is traversed from its centre to its boundary, but this time there is a discontinuity in passing into the blue zone. The copper content at the centre of the grain is at the limit of detection (0·1–0·2% ?), and increases continuously to 1% at the boundary of the blue zone; there it jumps suddenly to 2%. In this zone it varies continuously, as far as it is possible to measure the variation in a zone about 12$\mu$ wide, from 2% to 3%. On leaving this zone the Cu content increases to 4% and continues to increase to about 9%.

Thus the presence of three Cu–Fe–Sb phases has been demonstrated, which can only be identified with certainty by antimony determinations.

## CONCLUSIONS

The few examples presented in the paper give only a faint idea of the possible applications of the micro-analyser. They are the result of only two months' work, which in itself indicates how rapid and effective this new instrument is.




*At top:* Cu + Fe–Cu–P eutectic

**Fig. 10—Diffusion of Cu–P alloy into iron (frontal diffusion). Etched with nital** × 70

**Fig. 11—Diffusion of Cu–Sb alloy into Fe: grain boundary diffusion of Cu and aureoles in the Fe grains. At *B* aureole coloured blue by the etchant** × 350

Used alone, the instrument's field of application is quite wide but, when used in conjunction with a method for revealing the distribution of elements with which it cannot cope (light elements like carbon, nitrogen, and oxygen, or elements in concentrations too low, such as P and S in steels), one may expect extremely interesting results concerning the solid-state interaction of certain metallic elements with the non-metals always present in alloys.

Another possible application of the microanalyser which has not yet been explored at IRSID is local crystal analysis by Kossel diagrams. Castaing[1] has been able to obtain such diagrams, which permit the crystal study of a region of about 5$\mu$ radius, in which Kossel lines are produced.

Thus, used only for elementary and crystal analysis, or in combination with complementary methods (e.g. autoradiography), the microanalyser is capable of producing great advances in knowledge of the structure of metallurgical products.

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# Some Factors Affecting Electrode Consumption in the Electric Arc Furnace

*By D. H. Houseman, M.A., Ph.D.*

SYNOPSIS

The direct-potential-drop method of electrode resistivity measurement has been used to sort 498 10-in. dia. electric-furnace electrodes into groups on a resistivity basis in order to show that there is a direct and statistically valid relationship between electrode resistivity and electrode consumption in the two basic arc furnaces used in the investigation. Long-term trials, using only electrodes of low and medium resistivity, have shown that large savings are possible in electrode costs.

Estimation of the average bulk density of 483 electrodes whose mean electrical resistivity is known indicates that there is an inverse correlation between electrode bulk density and resistivity, but the low accuracy of the correlation makes density estimation unsuitable for use as an acceptance test, despite its simplicity.

The discussion attempts to assess the relative parts played by the electrode supplier and the steelmaker in influencing electrode consumption and points out the special advantages, in highly-rated oxygen-blown arc furnaces, of using only electrodes of low resistivity. 1174

## Introduction

DATA COLLECTED from routine furnace operations have shown electrode consumption to be a very variable factor. In some periods, consumption has risen to twice that in others. Though many factors (power input, furnace lining, steelmaking technique, etc.) influence these variations, nevertheless in a period in which all known external variables are kept constant, wide variations in electrode consumption are observed. Figure 1 illustrates this, the data being obtained over 20 months during which two furnaces of 5-ton nominal capacity were operating with basic linings and 3500 kVA input. Most 4-week periods show an electrode consumption of about 13 lb/ton, but there are five periods in which consumption is considerably above this. An increase in consumption of even 1 lb per ton during an average period means, on a basis of 1600 tons of steel produced, an increase in electrode cost of £110. It is clear, therefore, that the causes of these fluctuations require investigation both from the standpoint of cost reduction and from that of improving the technical efficiency of the steelmaking process.

A recent paper[1] of the Electric Process Sub-Committee of the Steelmaking Division of B.I.S.R.A. discussed some factors affecting the wear of graphite electrodes and pointed out that studies of the relative importance of these factors were complicated by extraneous effects attributable to electrode quality, which swamped the effects due to other variables; the paper described two techniques for measurement

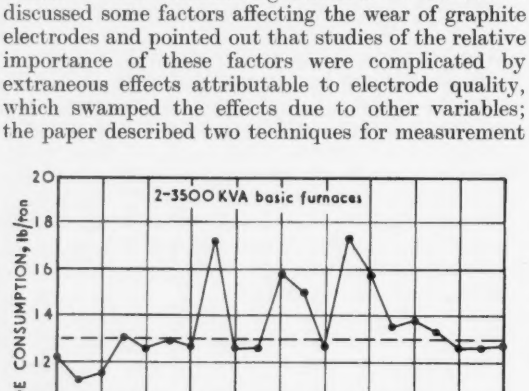


**Fig. 1—Electrode consumption in two 3500-kVA basic arc furnaces using 10-in. dia. graphite electrodes**

of the electrical resistivity of individual electrodes and it was decided to use one of these, namely the direct potential-drop method, to study the relationship between electrode consumption and resistivity. A statistical examination was also made of the relationship between the average bulk density of an electrode and its mean resistivity, since this could lead to a more conveniently applied routine control procedure, estimations of bulk density being easier and more rapid than those of resistivity. Preliminary results obtained in both these investigations have already been briefly reported.[2]

## APPARATUS AND TECHNIQUE

### Experimental Apparatus for Resistivity Determination

In the formula for electrical resistivity, $\rho = R.A/l$ (where $\rho$ = resistivity, $R$ = resistance, $A$ = cross-sectional area of electrode, and $l$ = length across which $R$ is determined), $A$ and $l$ are obtained by mensuration while $R$ is determined from Ohm's Law $R = E/I$ by measuring the quantities $E$ (in volts) and $I$ (in amperes) using the simple circuit shown in Fig. 2. The circuit is essentially similar to that described by Brandt and Glaisher[3] and by the Electric Process Sub-Committee[1] and needs no further discussion here.

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Dr. Houseman was Research Metallurgist with K & L Steelfounders and Engineers Ltd., Letchworth, when the work described in this paper was carried out; he is now W. J. Rees Research Fellow in Refractory Materials, Dept. of Metallurgy, Sheffield University.

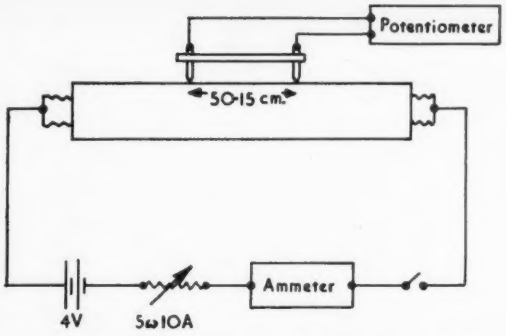


**Fig. 2—Circuit for measuring electrode resistivity**

### Technique for Resistivity and Apparent Density Determination

Graphite nipples having special steel terminals in their end faces are screwed into the end of the electrode under test. The circuit is completed as shown in Fig. 2, using the rheostat to adjust the current to an accurately known value between 10 and 12 A. The potential drop is measured using a specially constructed pair of test probes in connection with a portable potentiometer. The probes are held 50·15 cm apart by a rigid insulated bar and connected directly by low-resistance cable to the potentiometer. Three determinations of potential drop are made along the length of each electrode (at constant current input), one near each end and one at the middle of the electrode. Provided that the 'end' determinations do not include the region of the nipple where the current enters the electrode, the measured potential drop is substantially independent for this reason, 'end' determinations are usually made, (on 10 in. dia. × 72 in. long electrodes) with the outer probe some 6 in. from the extreme end of the electrode. The mean value of these three determinations is referred to henceforth as the 'mean resistivity' of the electrode.

The apparent density of each electrode is computed from data obtained as follows: (*a*) length $l$ by direct measurement, (*b*) diameter $d$ by taking the average of 100 determinations on 25 electrodes (*c*) weight $w$ by using the manufacturer's dispatch weight marked on the electrode.

## RESULTS

### Accuracy of Results

Resistivity, $\rho$, is obtained by substituting the expressions $R = E/I$ and $A = \pi d^2/4$ in the formula for resistivity $\rho = R.A/l$, to give: $\rho = \pi d^2 E/4lI$.

Of these quantities, $d$ is the most difficult to obtain in routine examinations. It was therefore estimated by making four measurements of diameter on each of 25 electrodes; this gave the value for the diameter as: $d = 9{\cdot}95 \pm 0{\cdot}10$ in.* This value of $d$ was used in all calculations for resistivity and bulk density. By making $l = 50{\cdot}15$ cm, the c.g.s. value for $\pi d^2/4l$ becomes 10—a convenient constant—so that: $\rho(\mu\Omega\text{-cm}) = 10E/I$ (volts/amps).

This device saves much calculation. $E$, $l$, and $I$ are all measurable to an accuracy of 0·2% or 0·3% but the use of the above value for $d$ means that values for $\rho$ are accurate only to about ±2·5%.

Similarly, in the formula for density, $D = 4W/\pi d^2 l$, as $W$ is known to ± 0·3%, $D$ is known to be about ±2·5%. These inaccuracies are sufficiently small not to obscure any significant relationship that may exist between either of these quantities and electrode consumption.

### Resistivity and Bulk Density Data on Incoming Electrodes

All electrodes in stock on 1st February, 1954, and all those received in the subsequent eight months, were examined for resistivity and bulk density using the methods just described. In all, 498 10-in. dia. electrodes were examined; representative results are given in the Appendix. Electrodes may roughly be divided into two groups in this table: those of low mean resistivity, where all three resistivity values are similar, and those of high mean resistivity where the values at the ends are appreciably higher than that in the middle. The significance of this latter group in steelmaking operations will be further discussed later.

Figure 3 consists of histograms showing the distribution of mean resistivity among the electrodes in six batches. Following a discussion with the electrode suppliers in July, 1954, during which the latter offered to facilitate these trials, a distinct reduction in average resistivity is observable in batches IV to VI as compared with batches I to III.

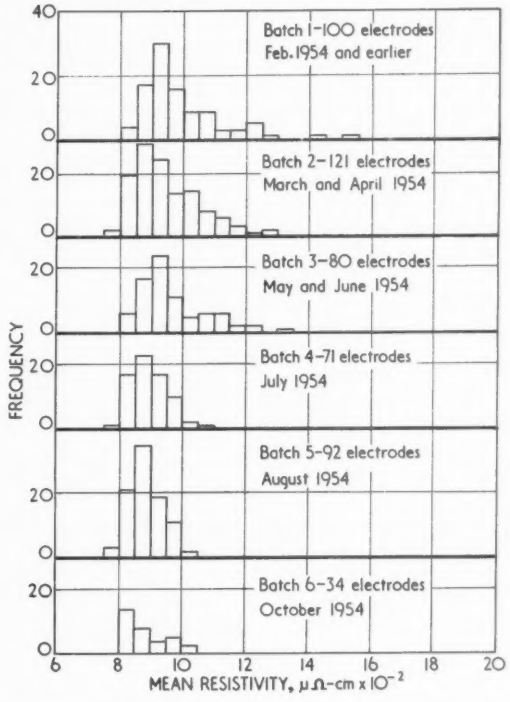


**Fig. 3—Resistivity measurements on incoming electrodes**

* The electrode manufacturers have since stated the diametral tolerances to be given by $d = 9{\cdot}97 \pm 0{\cdot}09$ in.

**Table I**

**ELECTRODE CONSUMPTION, INCLUDING BREAKAGES**

| Batch | Furnace | No of Electrodes Used | Weight of Electrodes Used, lb | Weight of Steel Produced, tons | Average Resistivity (X) | Electrode Consumption lb/ton |
|---|---|---|---|---|---|---|
| Group I (below 900 μΩ–cm) | A | 7 | 2270 | 217·75 | — | 10·4 |
| | B | 9 | 2843 | 271·10 | — | 10·5 |
| | Total | 16 | 5113 | 488·85 | 865 | 10·5 |
| Group II (901–1000 μΩ–cm | A | 17 | 5721 | 461·70 | — | 12·4 |
| | B | 15 | 5050 | 470·30 | — | 10·75 |
| | Total | 32 | 10771 | 932·00 | 945 | 11·55 |
| Group III (1001–1100 μΩ–cm) | A | 13 | 4427 | 377·40 | — | 11·7 |
| | B | 15 | 4631 | 372·40 | — | 12·4 |
| | Total | 28 | 9058 | 749·80 | 1038 | 12·1 |
| Group IV (1101–1200 μΩ–cm | A | 5 | 1868 | 148·3 | — | 12·6 |
| | B | 6 | 1977 | 160·3 | — | 12·3 |
| | Total | 11 | 3845 | 308·6 | 1135 | 12·5 |
| Total | | 87 | 28787 | 2479·25 | | |
| Average | | | | | 996 | 11·66 |

**' Grouped ' Electrode Consumption Trials**

During the testing of incoming batches of electrodes, those having mean resistivities in the ranges 801–900, 901–1000, 1001–1100, and 1101–1200 μΩ–cm, were set aside in groups until enough in each group had been collected for electrode consumption trials.

Each group of electrodes was taken in turn and used in an examination of electrode consumption in relation to tonnage of steel produced. A test started with the next heat in which all six electrodes in the two furnaces were of the given group in the melting zone, and continued until the supply of electrodes in the group had been used up. The results are shown in Tables I and II; the former takes into account total electrode consumption including all breakages from whatever cause, while the latter includes only breakages that are attributable to electrode quality (*see* Discussion). The data of Table II are thus more closely related to the physical properties of the electrodes, since breakages have a purely random incidence dependent entirely on the user.

Figure 4 illustrates these results; a linear relationship exists between resistivity and electrode consumption in both cases. Statistical examination of the data shows that the correlation of mean resistivity and electrode consumption is high. The statistics are given in Table III ; they show that the correlation is slightly improved by taking into account breakages not attributable to electrode quality.

A further batch of seven electrodes, all used in one furnace, having mean resistivities greater than 1200 μΩ–cm was found to yield an electrode consumption of 13·7 lb/ton (average resistivity 1291 μΩ–cm). This is in good accord with the data of Table I, but

**Table II**

**ELECTRODE CONSUMPTION, ALLOWING FOR BREAKAGES NOT ATTRIBUTABLE TO ELECTRODE QUALITY**

| Batch | Furnace | No of Electrodes Used | Weight of Electrodes Used, lb | Weight of Steel Produced, tons | Average Resistivity | Electrode Consumption lb/ton |
|---|---|---|---|---|---|---|
| Group I (below 900 μΩ–cm) | A | 7 | 2170 | 217·75 | — | 10·0 |
| | B | 9 | 2743 | 271·10 | — | 10·1 |
| | Total | 16 | 4913 | 488·85 | 865 | 10·1 |
| Group II (901–1000 μΩ–cm) | A | 17 | 5693 | 461·7 | — | 12·4 |
| | B | 13 | 4550 | 470·3 | — | 9·7 |
| | Total | 30 | 10243 | 932·0 | 945 | 11·0 |
| Group III (1001–1100 μΩ–cm) | A | 13 | 4327 | 377·4 | — | 11·5 |
| | B | 15 | 4131 | 372·4 | — | 11·1 |
| | Total | 28 | 8548 | 749·8 | 1038 | 11·3 |
| Group IV (1101–1200 μΩ–cm) | A | 5 | 1768 | 148·3 | — | 11·9 |
| | B | 6 | 1977 | 160·3 | — | 12·3 |
| | Total | 11 | 3745 | 308·6 | 1135 | 12·1 |
| Total | | | 27449 | 2479·25 | | |
| Average | | | | | 996 | 11·14 |

**Table III**
**CORRELATION BETWEEN MEAN RESISTIVITY AND ELECTRODE CONSUMPTION**

| | Data of Table I | Data of Table II |
|---|---|---|
| Correlation coefficient $r$ | 0·964 | 0·981 |
| Degrees of freedom | 3 | 3 |
| Probability of $r$ | 0·75% | 0·50% |
| Significance of $r$ | Highly significant | Highly significant |

has not been included therein as the small number of electrodes available makes the accuracy of the determination rather low.

Thus it may be concluded that, in the range of electrode resistivity 800–1300 μΩ–cm there is a direct relationship between electrode consumption and mean resistivity so that any lowering of the resistivity of incoming electrodes will result in a lowering of electrode costs in the furnace. A lowering of electrical resistivity may possibly be accompanied by an increase in other costs, and this is considered later.

### Long-term Trials of Electrode Consumption

Electrode consumption in the 52 weeks immediately preceding the electrode consumption experiments (April, 1953–April, 1954) averaged 13·92 lb/ton and was estimated, for 1954–5, at 13 lb/ton. Throughout the 15 weeks from 28.8.54 to 4.12.54, both arc furnaces were operated exclusively with electrodes having resistivities of 1000 μΩ–cm or below. The results, for *A* and *B* furnaces, are shown in Table IV. These results show that, throughout the 15 weeks, electrode consumption was well below expectation. The consumption figures for *A* and *B* furnaces were similar and the overall average electrode consumption was 10·65 lb/ton of steel in the ladle. As the histograms for batches IV–VI of Fig. 3 indicate, the average resistivity of incoming electrodes is about 875 μΩ–cm. From Fig. 4 it may be predicted that total consumption, including breakages, should be about 10·75 lb/ton. This prediction is closely in accord with the actual figure of 10·65 lb/ton achieved during the 15 weeks' trial.

### Economic Considerations

As Table IV shows, during 15 weeks a total of 6438 tons of steel were produced at an average electrode consumption of 10·65 lb/ton, i.e. 2·35 lb/ton below the anticipated figure. Electrodes cost 16·74*d.* per lb so that the total saving averages £70 10*s.* per week. Also, there is a saving due to an 18% reduction in time for renewing and slipping electrodes.

### Correlation of Electrode Resistivity and Bulk Density of Electrodes

The data of the Appendix may be used in a statistical examination of the relationship between the average bulk density of an electrode and its mean resistivity. In the sample of 483 electrodes for which data are available, the correlation coefficient between these quantities is −0·3099, which is significant for 482 degrees of freedom, below the 0·1% level of probability. This indicates that there exists a valid inverse relationship between bulk density and resistivity, but further examination of the data indicates that the accuracy of the correlation is low, the coefficient of variation being about 22%, and it is doubtful if the time gained in the density estimations is worth the sacrifice of accuracy.

### Relationship between Electrode Consumption and Power Consumption

An analysis made by Cosh[4] of data supplied by McCafferty[5] indicated that, for a given diameter of electrode, there was some evidence that a fall in electrode consumption would be offset by a rise in power consumption. Electrode and power consumption were therefore compared in the 15 weeks immediately prior to the electrode trials (2.1.54 to 10.4.54) and the 15 weeks of the long-term trials (28.8.54 to 4.12.54). Results are shown in Table V. Figures are given for *B* furnace since the power consumption figures for *A* furnace were known to have been influenced by the use of water-cooled door arches and jambs, in place of the conventional types.

The data of Table V support Cosh's conclusion that a decrease in electrode consumption is accompanied by an increase in power consumption but, as column (4) shows, there remains a large overall saving in cost.

## DISCUSSION

The above results may be used in assessing the relative parts played by the electrode supplier and the steelmaker in influencing electrode consumption. Figure 4 indicates a direct relationship between electrode consumption and resistivity and this relationship is further supported by the data obtained in long-term trials (Table IV). Resistivity appears to be inversely related to average bulk density; this latter quantity is principally a function of the degree of graphitization of the electrode during manufacture. We may thus arrive, through these three links, at a tentative relationship between electrode consumption and manufacture.

The method of manufacture decides the degree of graphitization achieved by a given electrode and this in turn influences bulk density and resistivity and,

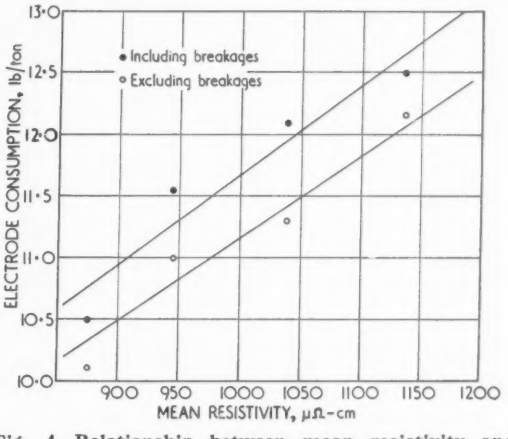


**Fig. 4—Relationship between mean resistivity and electrode consumption**

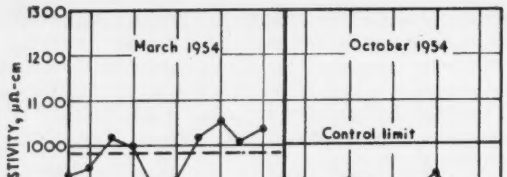


**Fig. 5—Quality control chart for 10-in. dia. graphite electrodes**

ultimately, electrode consumption. It seems then that electrode resistivity is a good final manufacturer's test and also a good customer's acceptance test; the manufacturer does, in fact, use this test where practicable as a check on electrode quality.

The wide range of electrode resistivities encountered in practice (800–1300 μΩ–cm) does not imply any lack of control in the manufacturing process, since the aim of the manufacturer is to produce as economically as possible; rather does it mean that, if a particular consumer requires electrodes of a lower resistivity, and thus of a lower consumption per ton of steel, than the average, he must be prepared to specify an acceptable resistivity range on the basis of his own experience. We are now able to do this at K & L Steelfounders and Engineers Ltd., where an acceptable range of 1000 μΩ–cm and below has been fixed for 10-in. dia. electrodes. A quality-control system for examination of incoming electrodes, based on batch-sampling, has been instituted and Fig. 5 shows the quality-control data for the first and last 100 electrodes examined in these trials, divided into batches of 10, the average resistivities of these batches being plotted. At least five of the first 10 batches would not meet the present upper control limit.

**Table IV**
**LONG-TERM TRIALS OF ELECTRODE CONSUMPTION (15 WEEKS)**

| Week Ending | A Furnace | | B Furnace | |
|---|---|---|---|---|
| | Steel Produced, tons | Electrode Consumption, lb/ton | Steel Produced, tons | Electrode Consumption, lb/ton |
| 28. 8.54 | 234·25 | 11·1 | 220·40 | 8·7 |
| 4. 9.54 | 224·80 | 11·0 | 209·30 | 12·0 |
| 11. 9.54 | 227·20 | 10·0 | 226·55 | 9·0 |
| 18. 9.54 | 219·25 | 11·0 | 207·35 | 13·0 |
| 25. 9.54 | 228·05 | 11·0 | 195·05 | 10·0 |
| 2.10.54 | 236·75 | 9·5 | 206·90 | 11·0 |
| 9.10.54 | 212·10 | 11·0 | 224·55 | 9·0 |
| 16.10.54 | 238·00 | 10·5 | 166·20 | 11·0 |
| 23.10.54 | 232·10 | 11·0 | 209·45 | 11·0 |
| 30.10.54 | 231·55 | 11·0 | 171·80 | 13·0 |
| 6.11.54 | 226·05 | 10·6 | 195·25 | 8·6 |
| 13.11.54 | 203·10 | 12·7 | 214·55 | 10·2 |
| 20.11.54 | 198·15 | 11·0 | 212·10 | 11·0 |
| 27.11.54 | 185·60 | 10·8 | 229·40 | 10·3 |
| 4.12.54 | 239·05 | 10·9 | 214·05 | 8·8 |
| Total | 3336·00 | | 3102·90 | |
| Average | 222·40 | 10·87 | 206·86 | 10·44 |

**Average electrode consumption on A and B furnaces = 10·65 lb/ton**

**Table V**
**RELATIONSHIP OF ELECTRODE CONSUMPTION AND POWER CONSUMPTION (B FURNACE)**

| Column | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | 2.1.54 to 10.4.54 | 2.8.54 to 4.12.54 | Percentage change from (1) to (2) | Net change in cost per ton |
| Average electrode consumption, lb/ton | 13·70 | 10·44 | −31 | −55 pence |
| Average power consumption, kWh/ton | 612·4 | 630·2 | +3 | +18 pence |

**Note: In column (4): electrodes charged at 16·74 *d.* per lb, power charged at 1*d.* per kWh.**

There is insufficient evidence to show conclusively whether a decrease in electrode consumption is generally accompanied by an increase in power consumption since the 3% rise in power consumption noted in Table V is scarcely greater than the accuracy limits (±2%) of the wattmeters used. In any case, since the electrical energy needed for the graphitization of electrodes is about 3 kWh per lb,[6] the amount of electrode needed to produce 1 ton of steel uses less than 40 kWh for its manufacture, while the steelmaking itself uses over 600 kWh. It is clear that, as the costs of electric power fall relative to those of other furnace heat-producing media, the cost advantages of using low-resistivity electrodes will increase.

Changes in melting technique can adversely affect electrode consumption, despite the best efforts of the electrode manufacturers. While decreased electrode consumption is only one of many factors contributing to steelmaking efficiency and lowered costs, it is an important one, and once it is controlled it is possible to use the resistivity test to sort electrodes into closely graded batches and to use these batches in trials on other steelmaking variables, without fear that the results will be nullified by inherent variations in electrode quality.

Finally, a word may be said on the difficulties that arise for the steelmelter in using high-resistivity electrodes. As mentioned earlier, these electrodes commonly have a higher resistivity at the ends than in the middle; e.g. 5·6% of 'end' resistivities, but only 0·4% of 'middle' resistivities, are above 1200 μΩ–cm, and that on electrodes of high resistivity throughout their lengths. This, together with the increased resistance due to imperfect contact between electrode and nipple, means that a high-resistivity region occurs near the electrode joint. The increased heating effect that results from this during use causes a more rapid

oxidation (*see* below) of the electrode at these joints and a ' neck ' is formed. Breakages may occur due to this necking during the early part of the melting cycle because of mechanical stresses set up when the electrodes bore into the scrap; melting conditions are here at their severest while removal of the broken electrode is troublesome at this stage. Doubtless the heating effect due to the higher resistivity of ' bad ' graphite electrodes near joins is further enhanced by the steady fall in thermal conductivity that occurs with increasing temperature. In the range 900–2000° C graphite oxidizes very rapidly, even in air,[8, 9] and this accounts for 60–90% of the total electrode wear.[7] It is thus especially important where oxygen blowing is used that electrode joints do not form ' hot spots ' if the rate of ' necking ' is not to be greatly accelerated with consequent increase in losses due to broken ends. Most of the improvement here lies with the manufacturer, but the user can ensure by careful handling and correct tightening torque, that the area of graphitic contact at the joint is as large as possible.

Thus, for reasons both of cost and of convenience, the use of high-resistivity electrodes in a highly-rated oxygen-blown arc furnace is undesirable and we have succeeded, through co-operation with the electrode suppliers, in minimizing this use.

## SUMMARIZED CONCLUSIONS

(1) There is a direct and statically valid relationship between electrode resistivity and consumption in the two basic arc furnaces used in the investigation.

(2) Long-term trials using only electrodes of low and medium resistivity have shown that large savings are possible in electrode costs.

(3) Electrodes may be sorted into standard groups, on a resistivity basis, for use in investigations of other variables in the steelmaking process.

(4) As electrode consumption decreases, power costs per ton of steel produced may rise; this rise is however more than offset by the fall in electrode costs so that a large net saving results from using low resistivity electrodes.

(5) While there is an inverse correlation between electrode bulk density and resistivity, the low accuracy of the correlation renders the former unsuitable for use as an acceptance test despite its simplicity.

## Acknowledgments

The work described in this paper was carried out in the Research Laboratories of K & L Steelfounders and Engineers Ltd., Letchworth, Herts. The author wishes to thank the Directors of the Company for permission to publish, and also to acknowledge the co-operation and encouragement that he received during the trials, from his colleagues Mr. A. C. Brearley (Chief Metallurgist), Mr. F. Crankshaw (Supplies Metallurgist), and Mr. R. E. Barleggs (Melting Shop Superintendent). Thanks are also extended to Mr. T. H. Mowbray (British Acheson Electrodes Ltd., Sheffield) and to several of his colleagues for helpful information and discussion.

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## APPENDIX

### AVERAGE BULK AND RESISTIVITY OF 10-in. GRAPHITE ELECTRODES*

| Serial No. | Bulk Density, g/cm³ | Resistivity, μΩ-cm | | | Mean Resistivity |
|---|---|---|---|---|---|
| | | End | Middle | End | |
| 1 | 1·585 | 780 | 895 | 845 | 840 |
| 11 | 1·580 | 935 | 905 | 825 | 888 |
| 21 | 1·540 | 1480 | 1250 | 1880 | 1537 |
| 31 | 1·525 | 1115 | 1070 | 1095 | 1095 |
| 41 | 1·620 | 795 | 795 | 810 | 800 |
| 51 | 1·560 | 1100 | 900 | 950 | 983 |
| 61 | 1·550 | 1040 | 980 | 1030 | 1017 |
| 71 | 1·605 | 1310 | 1060 | 1320 | 1230 |
| 81 | 1·570 | 1090 | 980 | 950 | 1007 |
| 91 | 1·550 | 1060 | 1025 | 1050 | 1045 |
| 101 | 1·575 | 1112 | 913 | 929 | 985 |
| 111 | 1·640 | 929 | 805 | 947 | 894 |
| 121 | 1·595 | 1063 | 885 | 1026 | 991 |
| 131 | 1·620 | 863 | 837 | 828 | 846 |
| 141 | 1·600 | 1028 | 896 | 840 | 922 |
| 151 | — | 1083 | 943 | 1028 | 1018 |
| 161 | 1·615 | 981 | 833 | 902 | 905 |
| 171 | 1·600 | 852 | 852 | 936 | 880 |
| 181 | 1·615 | 1115 | 968 | 1059 | 1047 |
| 191 | 1·600 | 790 | 820 | 895 | 836 |
| 201 | 1·560 | 1109 | 857 | 1044 | 1003 |
| 211 | 1·555 | 982 | 863 | 1000 | 948 |
| 221 | 1·610 | 858 | 830 | 803 | 830 |
| 231 | 1·620 | 825 | 903 | 990 | 906 |
| 241 | 1·630 | 950 | 880 | 1378 | 1070 |
| 251 | 1·615 | 1148 | 1108 | 1080 | 1112 |
| 261 | 1·605 | 972 | 852 | 695 | 840 |
| 271 | 1·625 | 952 | 893 | 796 | 880 |
| 281 | 1·555 | 990 | 915 | 1542 | 1149 |
| 291 | 1·550 | 983 | 825 | 895 | 902 |
| 301 | 1·565 | 1182 | 1016 | 1000 | 1067 |
| 311 | 1·580 | 956 | 830 | 870 | 885 |
| 321 | 1·615 | 1028 | 930 | 930 | 962 |
| 331 | 1·580 | 1132 | 935 | 925 | 997 |
| 341 | 1·570 | 918 | 838 | 1000 | 919 |
| 351 | 1·610 | 982 | 853 | 1035 | 957 |
| 361 | 1·550 | 1100 | 822 | 832 | 918 |
| 371 | 1·625 | 850 | 840 | 973 | 887 |
| 381 | 1·585 | 922 | 884 | 942 | 914 |
| 391 | 1·600 | 918 | 763 | 790 | 825 |
| 401 | 1·615 | 895 | 826 | 887 | 870 |
| 411 | — | 803 | 821 | 831 | 819 |
| 421 | 1·590 | 918 | 937 | 900 | 918 |
| 431 | 1·595 | 882 | 948 | 915 | 915 |
| 441 | 1·605 | 896 | 915 | 1170 | 994 |
| 451 | 1·615 | 673 | 818 | 955 | 815 |
| 461 | 1·630 | 912 | 876 | 885 | 890 |
| 471 | 1·650 | 833 | 852 | 939 | 874 |
| 481 | 1·615 | 868 | 842 | 938 | 882 |
| 491 | 1·625 | 883 | 837 | 812 | 844 |

*The author states that this table contains measurements for only every tenth electrode examined.—Ed.

# Instrumentation in Steelworks

## Part I—THE OPEN-HEARTH STEELWORKS

*By G. Husson*

SYNOPSIS

**The development of various measuring and recording instruments in recent years has made possible a greater degree of efficiency in the steelworks. Part I of this paper deals with the use in the O.H. steelworks of immersion pyrometers, pressure gauges, flow meters, total-radiation pyrometers, photoelectric cells, and suction pyrometers and the questions arising from instrumentation.**

**Part II deals with the advantages in a basic Bessemer steelworks of volumetric recording flow meters, two-colour pyrometers, flame pyrometers, and opacimeters.** 1290

THIS PAPER is not intended to be either a careful enumeration of the control instruments that can be used in the O.H. steelworks nor a critical study of their behaviour, for which the author is unqualified. The following questions will be dealt with from a metallurgical viewpoint: Can one speculate at present about the best method of following the operation of an O.H. furnace? What factors should be measured? Is there any advantage in controlling some of them automatically? How should the readings of such apparatus be used?

Such questions have not been posed for a long time. The scope for realization of the possibilities indicated is obviously limited at any one time by the instruments and equipment available. It is only since the end of the war that the measuring instruments suitable for giving the right answers to these questions have become available in ever-increasing quantities.

Thanks to the work done in all the major metal-producing countries, and particularly in the U.K., there are now available immersion pyrometers for measuring the temperature of liquid steel, pressure gauges for measuring the pressure in the furnace laboratory, and flow meters which undoubtedly operate more easily on furnaces heated by rich gas or by liquid fuel than on the older furnaces heated by producer gas, although they can be adapted for use on these latter furnaces. For determining roof temperatures, there are also sighting instruments in which the sensitive measuring element is either a total-radiation pyrometer or, better still, a photoelectric cell. Finally, the suction pyrometer has been so improved that, although perhaps not yet universally applicable in steelworks, it is at least an instrument of reference whereby correlations can be established between the true temperature of the combustion gas or air and the relative indications or readings of the more conventional measuring instruments located in the checker chambers.

As already stated, the U.K. has played a great part in these developments; it was there that the suction pyrometer was invented, and that the idea of using photocells for measuring roof temperatures was conceived and a particular roof-pressure gauge was worked out by B.I.S.R.A.

Along what lines should these instruments be used? What are the most important variables to be measured? The fundamental principles which should govern the installation of control instruments in an O.H. furnace seem to the author to be as follows.

The control of operation of such a furnace should always be matched to the great variations in the conditions of melting down and refining; this calls for the exclusion of complete automation in itself, quite apart from general and human reasons which point the same way. This can, of course, be envisaged only in the fairly distant future and the author is not *a priori* in favour of it.

The human intelligence alone, wrote Descartes, can be a universal instrument. This thought seems to be echoed in the opinion often expressed, even in the U.S.A., that no sort of automatic control can replace a good operator. Although, in my opinion, good control means saving the operator from continual activity to ensure the constancy of the variables at fixed levels, it should at the same time allow him to modify these values in accordance with the perpetually changing conditions.

During the discussion of one of his papers at the November, 1948 meeting of The Iron and Steel Institute, Mr. H. Baker said that proper exploitation of the instruments installed requires that they should be *adopted*, and not simply *suffered*, by the personnel of the steelworks. This is very true. It would be illusory, therefore, to hope to obtain this result with the suppression of all initiative in the furnace crew and the creation of the 'robot' mentality, which would represent a human regression, since it would destroy not only human personality but also professional conscience and social cohesion.

Where producer gas is not used, present-day technology seems to have reached a definitive stage in relation to the means for maintaining regularity of the various input variables at prescribed values. But much remains to be done towards determining the data enabling these values to be prescribed satisfactorily. In this field, we are still in the trial stage. Satisfactory information is needed about the conditions of heat transfer from flame to bath, and certain measuring instruments must be developed.

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Monsieur Husson is Head of the Steelworks Division of IRSID.

Most of these instruments already exist, even though they are of recent origin, and they are being improved continually. Although they still have not been adapted to routine industrial use, they do at least permit research to be made with and on them.

Knowledge about heat transfer is much less advanced. A systematic study of flames, undertaken in 1948 at Ymuiden by an International Committee comprising representatives from the various industries interested, and on which the steel producers of the U.K. and France are represented by B.I.S.R.A. and IRSID, has already produced a considerable body of information, but this study still requires considerable expenditure and much labour. It should be complemented by a systematic study of the aerodynamics of furnaces, derived from simultaneous studies on reduced-scale models, on experimental furnaces, and on full-scale industrial furnaces. Aerodynamic processes govern the development of flames and determine the conditions of the mixing of fuel and air, and the recirculation of burned gas, one of the most important revelations of the first tests at Ymuiden.

For the last 10 years reduced-scale studies have been pursued in the U.K. for furnaces run on liquid fuel and cold rich gas. Similar studies were started in France a year or two ago, in collaboration with the Laboratoire Dauphinois d'Hydraulique at Grenoble and after an agreement with B.I.S.R.A., on furnaces run on mixed gas and low-calorific-value preheated gas. The results of this long-term research should enable the important factors to be identified in a few years' time.

However, it seems essential, if one wants to control a heat properly, to limit the number of operating variables to the absolute minimum. Misunderstandings on this subject are liable to render fundamental information useless by embedding it in a matrix of inessentials.

It is necessary therefore to single out the important variables. Various experiments now in progress at steelworks show that this will not be very easy because of the multiple interactions which can occur between these variables : roof pressure, ageing of the furnace, air/gas ratio, shape of the flame, etc. The interesting work of Thring[2] shows, however, that one of the determining factors in the acceleration of heat transfer is the maintenance of the roof at a temperature as near as possible to the safety limit. But it is obvious that the dependence of the operator upon his eye as the sole means of assessing the roof temperature obliges him to keep the roof at a temperature well below this limit, and this has an adverse effect on radiation, which depends on the fourth power of the temperature. This is the reason for the interest in roof-temperature measurements.

On the other hand, the cooling effect of parasitic air is considerable, and the correct control of combustion becomes impossible, even when this is only slight. From this an objection has even been derived to certain installations. In particular, the installation at Park Gate, described by Marshall and White,[3] was based on the idea that it would perhaps be illusory to control the combustion air delivered to the checker chambers, if the parasitic air excess is as much as 100%. The Park Gate furnaces were therefore at this period controlled to constant air flow ; the oxygen needed during refining for burning the liberated carbon monoxide was thought to compensate for the reduction of the volume necessary for combustion during the refining period proportional to that needed during the meltdown period. This is also referred to in a paper by Leckie.[4]

This method, if it can be justified from the present state of knowledge, is merely a makeshift. Even supposing that for refining with ore (a procedure widespread in the U.K.) the contention about the influence of the volume of air needed for the combustion of CO liberated by the bath is correct, it is likely to be much less exact for refining with scrap, which is general French practice. Such a view is simply an admission of impotence and shows how necessary it is to seek in the future some means of limiting the entry of parasitic air by careful control of the pressure in the laboratory and by proper attention to the sealing of the masonry and the reversal equipment. This tightness can be considerably increased by the substitution of register valves for the old-fashioned reversal devices using bells or butterfly valves.

This will obviously not be easy in view of the experiments described; even with a pressure that is correct according to the laboratory, there is air ingress through the masonry of the flues or checker chambers in natural-draught furnaces, and considerable losses of air from those operated on blast, either through the reversal equipment, or across the masonry. It will need a great deal of work and development to achieve better masonry tightness, but it would be worthwhile. Until then the determination of the oxygen content of the flue gas will be indispensable for correction of the air/gas ratio adopted. Unfortunately it does not seem possible to use the flue-gas analyser itself as a controller, since its response time is much too long owing to the inertia of the furnace plus its own.

At present the essentials of the instrumentation of an O.H. furnace should therefore be :

(i) Automatic draught control, ensuring constancy of pressure in the laboratory
(ii) Manual control of fuel flow, by the furnaceman, with a roof-temperature indicator
(iii) Automatic control of the flow of air and, for heating by fuel oil, of the flow of the atomizing agent, at a ratio to gas flow which would leave the operator the chance of varying the excess air, checked by flue-gas analysis, according to furnace needs.

The reasons which seem to justify the adoption of automatic control of the pressure, but not of the fuel flow, are :

(i) Greater constancy desired for the pressure
(ii) Possible variation in the optimum roof temperature during the phases or with the special features of the operation, and also the fact that measurements of roof temperature are only possible at isolated points, which does not eliminate the need for overall visual observation of the roof ; it can happen accidentally that the points sighted by the pyrometer are not the hottest ones, or that dirty objectives falsify the readings.

These fundamental measurements obviously do not exclude others such as that of the pressure at different points of the circuit (which can assist in detecting obstructions during a campaign), of temperatures of checker chambers, and of the gas in the flues. It

is, for example, necessary that the furnaceman should know the temperature of the chambers, to enable him to control reversal better. This temperature is certainly of prime importance in the running of the furnace.

But these are complementary measurements, the control and running of the furnace being based essentially on those indicated above.

Once these quantities have been measured and recorded, the problem of using them remains. It has been shown that there are multiple interactions between the variables: e.g. for a given roof pressure, the distribution of pressures in the laboratory (and therefore the parasitic air) can depend on the flows of fuel and air and on the flame direction.

Even if the characteristics of the flame could be controlled at will, the optimum characteristics would still not be known. The Ymuiden work is beginning to reveal the factors which affect flame radiation, but the extent to which the flame heats by radiation and by convection is still unknown, at any rate on a cold charge. At IRSID[5] it has recently been established that an increase of the proportion of atomizing agent in a fuel oil-fired furnace, and consequently its momentum, shortens the flame, reduces radiation, and speeds up meltdown. The same work demonstrated that steam atomization seems to initiate a considerably more rapid oxidation of the reducing elements in the charge than air atomization. We are beginning to know what factors determine the length of the flame, but we still do not know whether the best flame is short or long. It may be that one of these is correct for rich fuels and the other for low-calorific-value gases, and that one should be preferred for meltdown and the other for refining. What should be understood by flame length ? Is it that part of the flame rendered visible by particles of glowing carbon, or does it extend to the point where the analysis of the gas on the axis of the flame indicates stoichiometric mixture and where combustion may be considered completed ? These are questions which can occupy the attention of research workers for several years to come.

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## Part II—THE BASIC BESSEMER STEELWORKS

*By P. J. Leroy*

For the past 75 years, the operator of a basic Bessemer has most often had to control the running of his converter with only a pressure gauge and a watch, to indicate the blast pressure and the time of the blow, respectively.

Apart from these two readings, the operator could only be guided by empirical signs, such as :

(i) Appearance of the flame
(ii) Possible slopping from the converter throat
(iii) Appearance of the slag when the converter is tilted
(iv) Degree of rimming action of a sample of the molten metal
(v) Appearance of the fracture surfaces of the sample
(vi) Possible ladle skulls, etc.

These signs are useful, but certain readings or recorded curves suitable for use either by the operator for the conduct of the operation, or to give the engineer better information about the blow conditions would also be valuable aids.

To develop and put into service a series of instruments to increase the efficiency of a basic converter has been one of the principal activities of IRSID since its creation under the particular stimulus of its president, Henri Malcor, who in 1947 outlined the programme of research on this matter.

In this paper it is intended to describe four of the instruments developed by IRSID:

(i) The Volume Debitgraphe (a volumetric recording flow meter) for controlling the blast
(ii) Two-colour pyrometer } for continuous temperature measurement during conversion
(iii) Flame pyrometer }
(iv) Opacimeter, for detecting the end-point.

The main variables to be measured and controlled in the operation of a basic Bessemer converter are:

(i) Total volume of the blast from the start of the blow to a given point, and the flow of blast through the tuyeres at this point
(ii) Temperature, which is of fundamental importance for dephosphorization (inhibited by too high a temperature) and for nitrogen fixation by the metal (more active the hotter the bath)
(iii) Correct determination of the end-point of the blow, which must be determined to within a few seconds; if the blow is stopped too soon, the phosphorus content of the metal is still too high; and if it is stopped too late, there is an excessive loss of iron in the slag and too much oxidation of the metal, with all the inconveniences resulting therefrom, such as, for example, excessive consumption of ferromanganese and poor control of the steel in the casting pit.

The object of the Volume Debitgraphe is to measure and record the flow of blast air through the converter, not merely as a function of the time from the start of the blow, but also as a function of the total volume of blast already passed at the instant in question. This decides the stage the process has reached ; the variation of temperature and the time for various additions should be governed by it. As will be seen, knowledge of this total blast volume also permits best possible control of the flow at each instant to limit the loss by slopping.

The two-colour pyrometer is used for recording automatically the temperature of the metal from the start to the end of the operation. The flame pyrometer plots a curve of the temperature of the converter flame, making corrections for its emissivity. This temperature is obviously related to that of the bath.

Monsieur Leroy is Engineer attached to the Head of the Steelworks Division of IRSID.

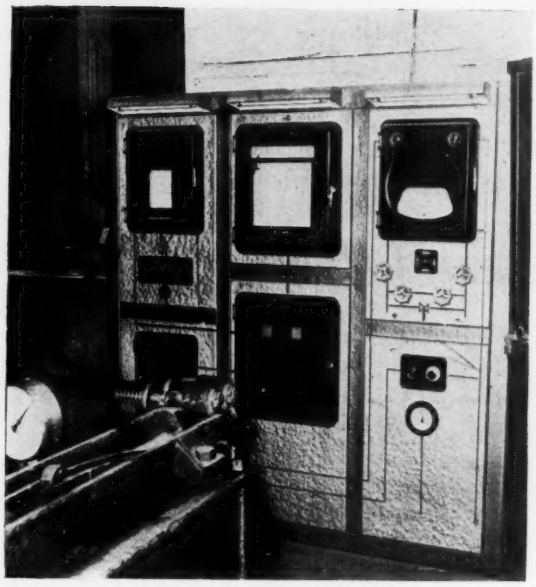

**Fig. 1—The Volume Debitgraphe**

Finally, the opacimeter provides an indication of the end-point of the blow based on the appearance of red smoke in the flame.

### THE VOLUME DEBITGRAPHE

This instrument (Fig. 1) was developed by the General Services Department of IRSID, in close collaboration with a French firm.[5] It is a flow meter of special type which enables two fundamental quantities to be measured and recorded:

(*a*) The flow of blast into the converter at each instant, expressed automatically in standard cubic metres per minute (at 0°C, 760mm)

(*b*) The total volume of air blown through the bath from the start of the operation to the required instant, which is the real variable, characterizing the development, much more than the time, of refining a given weight of pig iron.

The flow of blast at each instant is measured with a linear flow meter, operating from an orifice plate or a Venturi in the blast line. This flow meter is equipped for automatic pressure balancing, and it is calibrated at the mean blast temperature.

The recording strip of the instrument traces a flow-rate curve ; this strip is driven by an integrating device at speeds proportional to the instantaneous blast flow-rate. Hence the length of paper which is unrolled at a particular moment is proportional to the quantity of blast from the start of the blow, and not to the time. A counter, connected to the drive for the paper, indicates directly the total volume of air passed since the start of the blow.

The rig is completed by a pressure recorder. The simultaneous interpretation of the two curves for flow and pressure makes allowances for variations in permeability ; this quantity, defined by the flow of blast at a given pressure (e.g. 25 lb/in$^2$) mainly describes the resistance of the bottom to the blast.[7]

A variant of the Volume Debitgraphe[3] for ordinary air has been developed for use of more complex blast: e.g. oxygen-enriched, or steam–oxygen mixtures, etc. In this case the true variable is the quantity of oxygen from the start of the blow to the instant in question. The instrument summates this quantity, and can in this case become a proportion controller (Fig. 2).

The use of the Volume Debitgraphe on basic

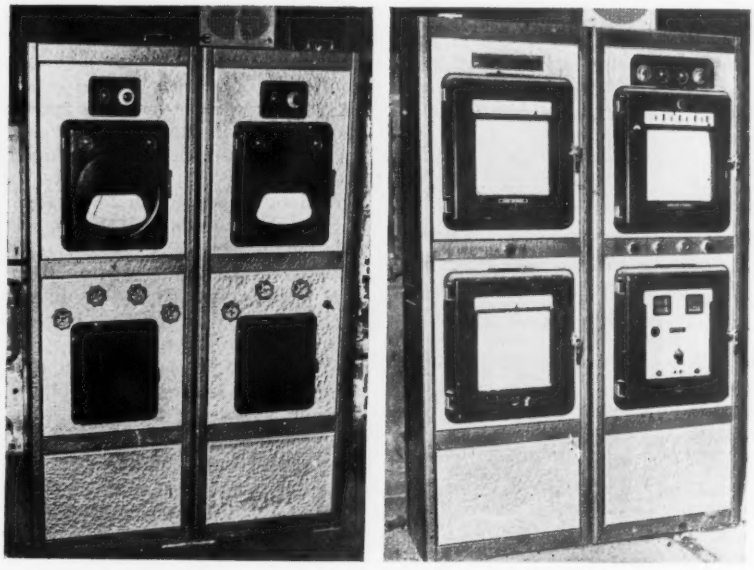

**Fig. 2—Volume Debitgraphe for use with oxygen-enriched blast, steam–oxygen mixtures, etc.**

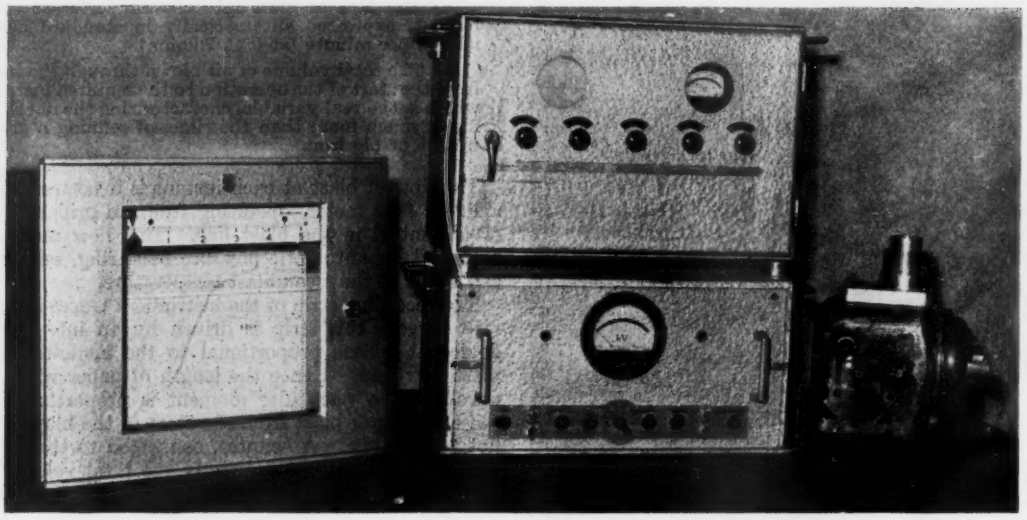

**Fig. 3—Two-colour pyrometer**

Bessemer converters has helped to solve the important problem of studying the factors which govern the slopping of metal during the first half of decarburization. This study has produced the following results.

Studies on reduced-scale models, made at the Laboratoire Dauphinois d'Hydraulique at Grenoble and later checked in steelworks, have shown that slopping is due to the superposition of two processes. The whole of the bath, under the influence of the blast from the tuyeres, is put into vibratory motion, which takes the form of a rotating wave. As the blast flow increases, the crest of this wave approaches the throat of the converter, and when it arrives at the lower lip slopping occurs. The height of the rotating wave depends, among other things, on hydrodynamic factors which can be studied on reduced-scale models and then checked on actual converters with the recording flow meter, and on physico-chemical processes. Slopping is most frequent and abundant with silicon-rich pig iron. This is explained by the fact that the first siliceous slag, which forms during the combustion of the silicon, in the first part of decarburization, has a considerable foaming power unless it is neutralized by a certain quantity of lime. Under the influence of this slag, mixed by the blast with the metal bath, the latter expands and the height of the rotating wave increases; thus slopping is facilitated. The only possible remedies for this foaming are to control the silicon content of the pig iron, to use more reactive lime, etc., all of which are physico-chemical matters. But, on the other hand, slopping can be controlled by diminishing the tendency to form the rotating wave and the uprearing of its crest. The Volume Debitgraphe has enabled us to confirm and extend the results already obtained at Grenoble on reduced-scale models.[2]

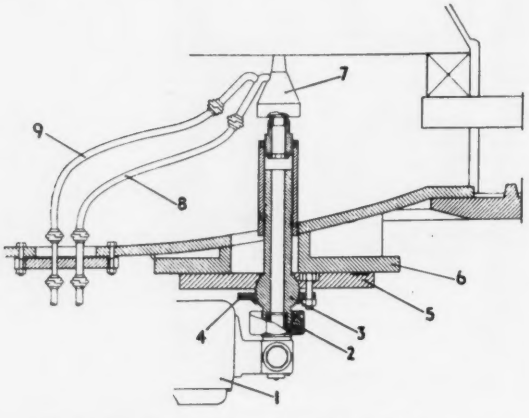


**Fig. 4—Sectional view of mounting on converter**

Slopping decreases or disappears when the static height of the bath decreases ; in particular, there is some progress in making the lower part of a new lining cylindrical, frequently with a slope or stepped. More generally, the internal diameter of the new lining should be large enough to prevent the static height of the bath exceeding 60 cm (about 2 ft). In France, this height is usually 70–80 cm (between 2 ft 4 in. and 3 ft). The lining wears during a campaign, and considerably improves blowability by diminishing the static height of the bath ; a better meridian shape for the lining also helps.

Contrary to what was commonly assumed, the blast zone must be as large as possible. This is the circular zone in which the tuyere outlets are located. The annular ring between the blast zone and the converter wall is called the ' external circulation zone.' In a converter with a given internal diameter, the level of the rotating wave is lower with an enlarged blast zone and a reduced external circulation zone. There is, therefore, some point in making bottoms as large as possible and distributing the tuyeres as uniformly as possible. Several French steelworks have

already modified the bottoms of their converters along these lines and are very satisfied with the results.[1]

In practice, the Volume Debitgraphe has provided, for a given converter, data for curves which indicate for each silicon content the flow-rate which must not be exceeded at any point if slopping is to be avoided. The minimum on these curves at the critical slopping time is the point where the foamy slag is produced. Provided that the blast rate is always kept below that indicated by the curve, slopping can be completely prevented.

Results from this instrument have confirmed those obtained by Malcor in 1933, that there exists what is called the 'permeability anomaly.' At a certain point of the blow, at the end of decarburization, there is in some cases a decrease in the permeability of the bottom which may cause a decrease of the flow-rate of the blast at constant pressure, an increase of the pressure to maintain a constant flow-rate, or even a reduction of flow-rate in spite of an increase of pressure. This phenomenon should be attributed to the formation at the tuyere nozzles of deposits of solid metal; the metal is at this moment very close to the liquids. The phenomenon only occurs in certain cases: (*a*) heats unusually cold at the end of decarburization, (*b*) an over-rapid increase of the blast flow-rate in each of the tuyeres.

Finally, the counter associated with the instrument (and the length of paper unrolled during the blowing of a heat) gives a check on the consumption of air per ton of pig iron, and its fluctuations with the composition of the pig and the static height of the bath.

### THE TWO-COLOUR PYROMETER (Fig. 3)

The two-colour pyrometer used was developed by the General Services Department of IRSID, and in particular by M. Rodicq and M. Maillot under the direction of M. Michaux. A similar instrument has been developed in Germany by Dr. Naeser.[8]

The instrument is sighted on the heat through a tuyere in the bottom. It receives the luminous energy comprised in two narrow bands of mean wavelengths $\lambda_1$ and $\lambda_2$, and records the temperature ($T$°K) of the bath given by:

$$\log \frac{i\lambda_1}{i\lambda_2} = A + \frac{B}{T}$$

based on the laws of Stefan[1] and Wien,[2] where the $i$ = the currents in the output from a photocell behind filters passing the wavelengths indicated by the subscripts, and $A$ and $B$ are constants.

The importance of using the ratio of the luminous energies at two wavelengths is that the measurement is not affected by factors which reduce or increase these two energies in the same ratio: this is the case, for example, for a variation in the solid angle of sighting (due to wear of the converter bottom, or slight plugging of the tuyere), or for contamination of protecting glass by the blast passing through the tuyeres, etc.

**Apparatus:**

This consists of

(i) A probe, whose mounting can be seen in Fig. 4, traverses the blast box. This probe has only one sensitive element, an electron multiplying cell, in front of which a disc rotates, carrying monochromatic filters for the wavelengths $\lambda_1$ and $\lambda_2$. Hence the same cell receives in succession the luminous energies in the wavelength bands of mean wavelength $\lambda_1$ and $\lambda_2$; a suitable electronic device enables the ratio of those two energies to be found. In this way, the complications which result from the differential ageing of two cells, each of which receive only one wavelength band, can be avoided

(ii) An electron circuit from which a current $I$ proportional to $\log i\lambda_1/i\lambda_2$ and thus to $A = B/T$ is produced from the currents $i\lambda_1$ and $i\lambda_2$

(iii) A recorder, calibrated directly in degrees

(iv) A double device for feeding oxygen and nitrogen to the tuyere, whose function is described below.

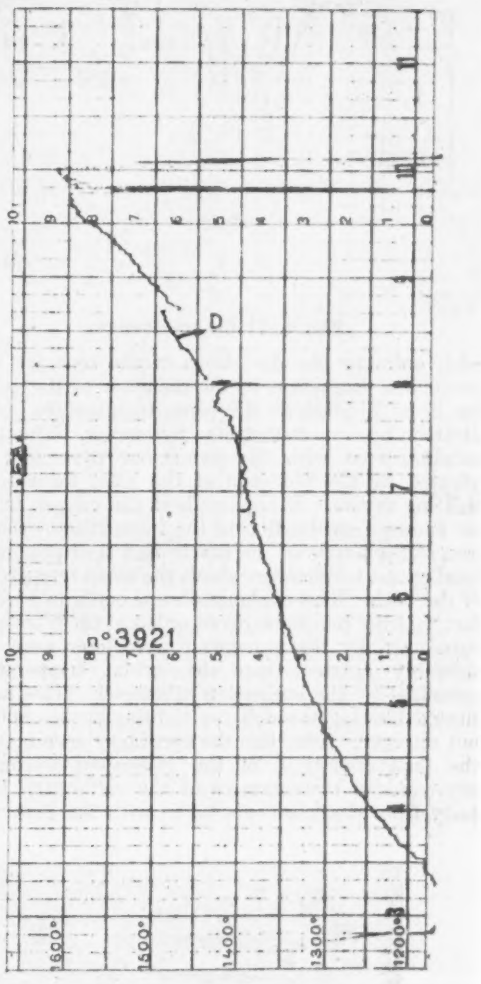


**Fig. 5—Temperature curve for a basic Bessemer heat**

No special difficulty has been encountered in the laboratory, in using this instrument, but the use of the curves recorded with it in a basic Bessemer steelworks was at first extremely laborious. For blowing

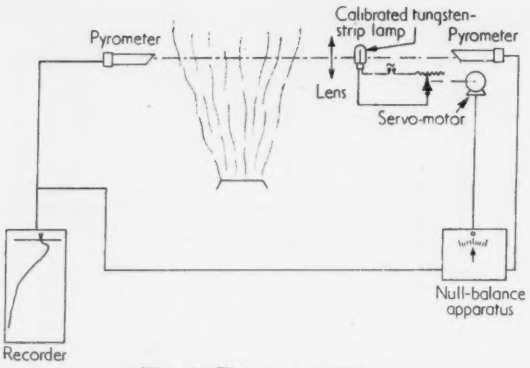


**Fig. 6—Flame pyrometer**

with ordinary air, deviations of the recorder were greater in proportion to the diameter of the tuyere for heats finished at the same temperature, as indicated by an immersion pyrometer. Thus the measurements with the two-colour pyrometer are affected by the flow-rate of the blast through the sighting tuyere. It appears that the oxygen in this air causes a combustion of the impurities in the pig iron at the nozzle of the tuyere and thus produces a local excess temperature above the mean temperature of the bath. This explanation was confirmed by the fact that the temperatures recorded at the moment of turn-down by the two-colour pyrometer were considerably greater than the actual temperatures measured by the immersion pyrometer. This necessitated blowing through the sighting tuyere not air, but nitrogen. After this the correspondence between the final deviations of the two-colour pyrometer expressed as temperatures of the calibrating black body from measurements taken with the immersion pyrometer after turn-down were satisfactory. But the tuyere obstruction indicated above occurs particularly easily at the tuyere nozzle through which nitrogen is blown, since the temperature there is lower than at the nozzle of a normal tuyere. Hence the equipment had also to be provided with an oxygen input. Should an obstruction be formed at the tuyere outlet, the nitrogen cock is closed and the oxygen cock opened ; the obstruction is cleared several times to get a complete clearance.

These two examples give an idea of the many difficulties encountered in developing the apparatus ; others were surmounted in turn. Figure 5 shows a temperature curve for a basic Bessemer heat. The following may be noted :

(i) Slight fall in bath temperature during the first half minute of the blow, due to cooling by lime and scrap
(ii) Sharp rise of temperature up to 4 min of the blow, due to desiliconization
(iii) Slower rise during decarburization, which becomes more rapid
(iv) Sharp rise in the last 3 min, due to dephosphorization.

The small breaks in the curve show the beginning of obstructions in the sighting tuyere, rapidly suppressed by a short injection of oxygen. Sometimes these breaks are much more noticeable than they are on this diagram.

From the present prototype two-colour pyrometers, we have already been able to obtain interesting information such as : (*a*) a heat receiving an excess of lime and very little iron scrap gives a temperature curve always higher than that of a charge normally cooled by scrap and finished at the same temperature ; (*b*) of two heats finished at the same temperature, that which yields a steel of the lower nitrogen content is the one whose overall temperature variation was lowest.

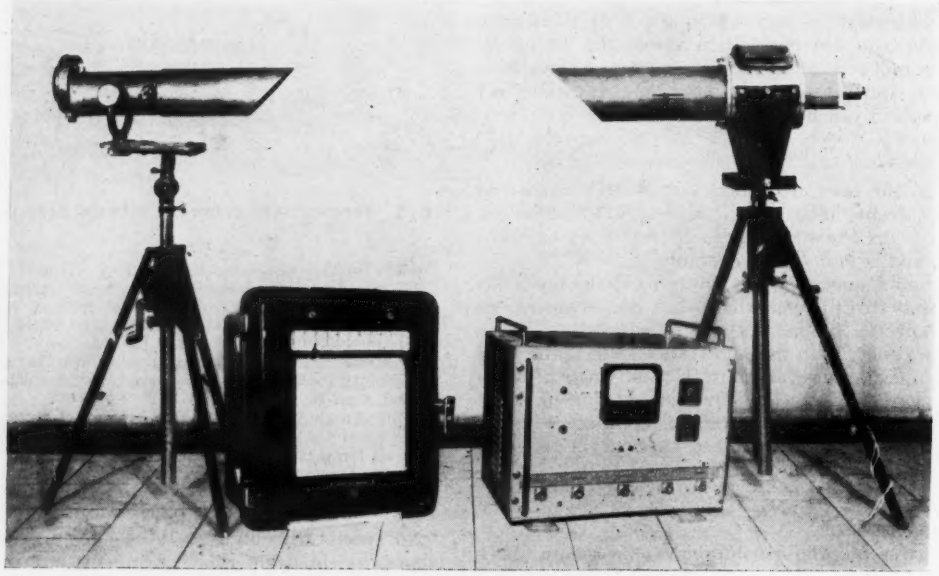

**Fig. 7—Components of flame pyrometer**

Studies with this instrument, conducted mainly by M. Trentini, the Steelworks Department of IRSID, are only just starting, and the field of investigation is vast. This instrument has already proved to be a research tool of first importance for investigating converter steelmaking. It is not yet possible to say whether it can become an instrument of practical industrial value.

## THE FLAME PYROMETER

The flame pyrometer was invented and developed by MM. Galey and Denis, of the staff of the Steelworks Department of IRSID.[6]

The two-colour pyrometer has been shown to plot directly the temperature curve for the metal bath. Another method for obtaining information about the bath temperature is to use the correlation which should exist between the temperature of the gases coming out of the converter and the temperature of the bath itself.

But the brightness temperature of a luminous flame depends on its true temperature and its emissivity. Knowledge of the brightness temperature is insufficient; therefore the investigators sought a temperature curve independent of the emissivity of the flame by using, in an entirely new instrument, the old method of Kurlbaum transformed into an automatic and null method.

Consider a source of light at one side of the flame (Fig. 6). The measuring pyrometer, equipped with a photocell, is sighted on this source across the flame, and receives luminous energy equal to the sum of (*a*) the energy emitted by the flame itself, and (*b*) the fraction of the energy emitted by the source which is transmitted by the flame after absorption therein.

A second pyrometer, placed behind the luminous source and sighted directly on the latter, receives directly the energy emitted by the source alone.

The luminous source, which is a controllable tungsten ribbon standard lamp, has, for a given flame temperature, only one brightness for which the responses of the two pyrometers will be identical. Theory shows that this response is a measure of the true flame temperature.

The difficulty in following fluctuations of this flame temperature was surmounted by coupling the circuits of the two pyrometers in opposition into a null-point instrument. If the flame temperature varies, equilibrium is disturbed. The null-point instrument controls a servo-motor which acts on the current feeding the light source and varies its brightness temperature until the out-of-balance is eliminated. The response of one of the pyrometers—the measuring pyrometer—is transmitted directly to a recording potentiometer. Thus after calibration, the instrument records the true flame temperature. Figure 7 is a photograph of some of the components of the instrument.

The flame pyrometer can be used for measuring the temperature of any luminous flame, provided that the emissivity of the flame is greater than 0·3 (which is true of most industrial flames), and that the flame temperature is fairly uniform. Obviously if this temperature is subject to considerable variations between one point and another it is impossible to speak any longer of a true temperature, for this no longer has any physical significance. However, in practice, when it is sighted on the flame of a basic converter, the instrument gives a particularly interesting dephosphorization curve, when there is no longer anything but nitrogen in the gas coming from the converter. Measurements of bath temperature with immersion pyrometers at the end of a blow have shown that the final flame temperature is systematically 80° C lower than that of the bath. This deviation can vary slightly from one works to another, but is always much the same at one particular works, so that the bath temperatures can be predicted from that of the flame.

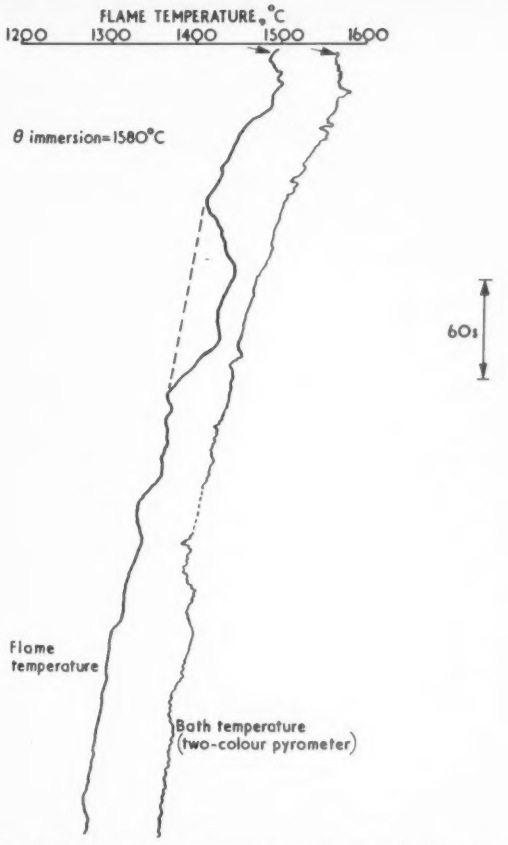


**Fig. 8—Temperature measurements on a basic converter**

In decarburization, the interpretation of flame temperatures is more difficult, due to combustion of CO to $CO_2$ at the converter throat. To prevent great interference from this, the optical path of the pyrometer should just graze the throat of the converter. But under this condition satisfactory results can be obtained even in decarburization, as has been proved on basic converters, and on an acid converter at the Workington plant of the United Steel Companies Ltd.

Figure 8 shows the temperature curve for a bath derived from a two-colour pyrometer, and the flame temperature curve for the same heat plotted with the flame pyrometer. The two curves are more or less

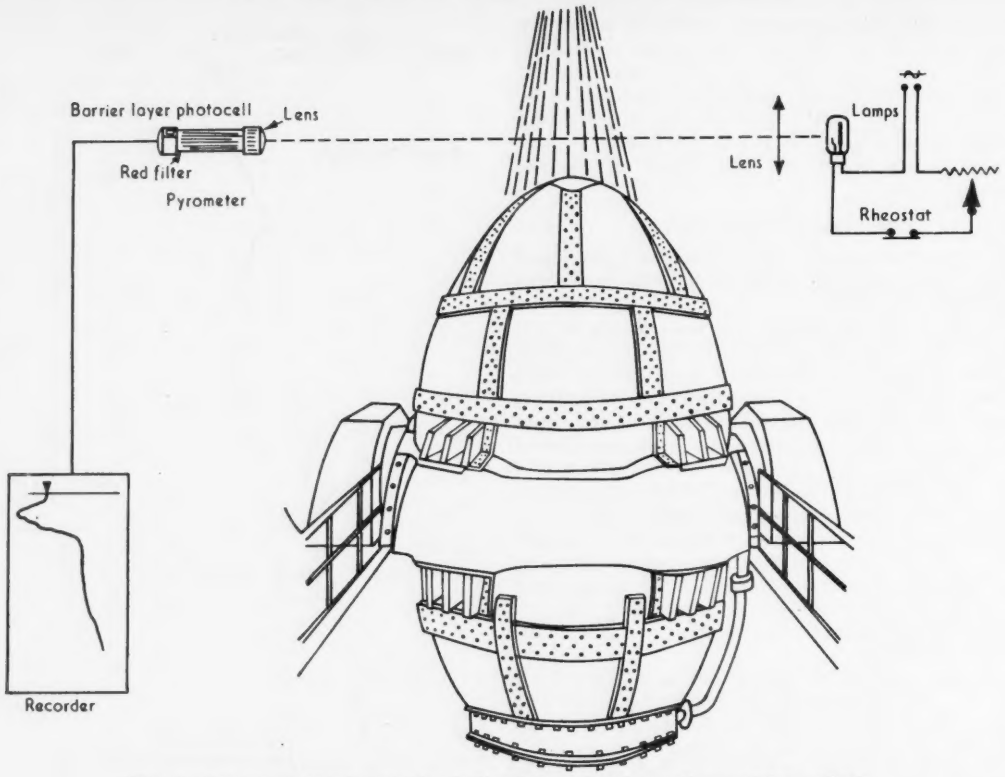


**Fig. 9—Set-up of opacimeter for indicating end-point and transition points**

parallel, except during the last 2 min of decarburization, where the effect of combustion of CO to $CO_2$ at the outlet from the converter throat makes itself felt.

This study of the flame pyrometer, of which only prototypes at present exist, is being continued. Of course, flame temperature is only an indirect index of the bath temperature, but the flame pyrometer is a simple and easily used research tool.

## THE OPACIMETER

The opacimeter was invented and developed by Galey, Leroy, and Denis.[7] It is a great deal simpler than the flame pyrometer. It comprises (*a*) a light source, at the converter throat level, sighted through the flame by a lens equipped with a photocell, and (*b*) a recorder whose pen motion is controlled by the cell current, after amplification. It is illustrated in Figs. 9 and 10.

The source brightness is constant, and not variable as in the flame pyrometer. It should be considerably brighter than the maximum brightness of the flame studied. Under this condition, the cell receives a luminous flux equal to the sum of the radiation from the flame and the energy of the light source transmitted by the flame, but this latter quantity preponderates because the brightness of the light source is considerably greater than that of the flame. Hence the shape of the curve is controlled mainly by variations in the opacity of the flame. We were led to study this quantity to obtain a signal of the end-point of the blow, in a basic converter.

The proper point for finishing the blow of a basic Bessemer heat is that at which the phosphorus content of the metal is sufficiently low, without the metal being excessively oxidized, and this requires timing to within seconds. Present practice is to assess the appropriate moment for the turn-down from the preceding heats relying on the time from the start of dephosphorization, and more particularly, on the appearance of the flame and of the fumes. The increase in the rate of oxidation of the bath makes itself felt at this point by the appearance and increase of red fumes, probably minute particles of ferric oxide, which gives a characteristic appearance to the flame always associated with over-oxidation of the bath once dephosphorization is finished.

But this visual estimate by an operator is necessarily subjective, and the accuracy with which he can spot the end-point decreases as the general temperature level of the heat increases.

A first supplementary reference point is provided by the counter of the Volume Debitgraphe. But three conditions are necessary to obtain a suitable phosphorus content of the metal at turn-down after passage of a certain volume of blast.

(i) The weight of pig iron must be known
(ii) The composition of this pig iron must not have changed since the heats on which control was based
(iii) The temperature level of the process must not have been changed.

The first condition is easy to satisfy, since the pig iron is weighed, but the other two are practically

impossible to adhere to under industrial conditions. Hence it was logical to try to find in flame observations a signal for the end-point to convert this qualitative assessment by the operator into something more quantitative. Experience has shown that the curve plotted by the opacimeter, after rising very sharply from the middle of dephosphorization, passes through a maximum which in many cases constitutes a good reference point for the end of the blow. After this it falls to a level portion whose onset constitutes another reference point, corresponding obviously to lower phosphorus contents than the other point. One may therefore turn down between these points, allowing a certain number of seconds at maximum opacity which depends on conditions peculiar to each plant and which must be fixed by the plant management at the most satisfactory point for the local conditions, allowing for the character of the heat and the phosphorus content envisaged. Studies are being pursued to define more exactly the effect, still only vaguely known, of certain metallurgical factors on the shape of the curve.

The two reference points for this curve (maximum and onset of final horizontal portion) are generally not very sensitive to temperature variations. For example, as Fig. 11 shows, a cold heat, finished at 1582° C, was turned down at 0·032% phosphorus in the steel and 9·8% iron in the slag; a hot heat, turned down at the same point on the curve, finished at 1645° C and gave a phosphorus content in the steel of 0·055% and an iron content of the slag of 10·45%.

The shape of the final part of the curve supplies in addition a qualitative indication of the temperature level of the heat, the maximum on the curve being normally sharp and pointed for a cold heat, wide and vague for a hot one.

The instrument is extremely simple and robust and is at present installed in 21 basic Bessemer steelworks in France and other countries of Western Europe.

## CONCLUSIONS

The aim in devising the instruments described above has been (*a*) to facilitate fundamental studies on the converter, and supply efficient research tools;

**Fig. 10—Components of opacimeter**

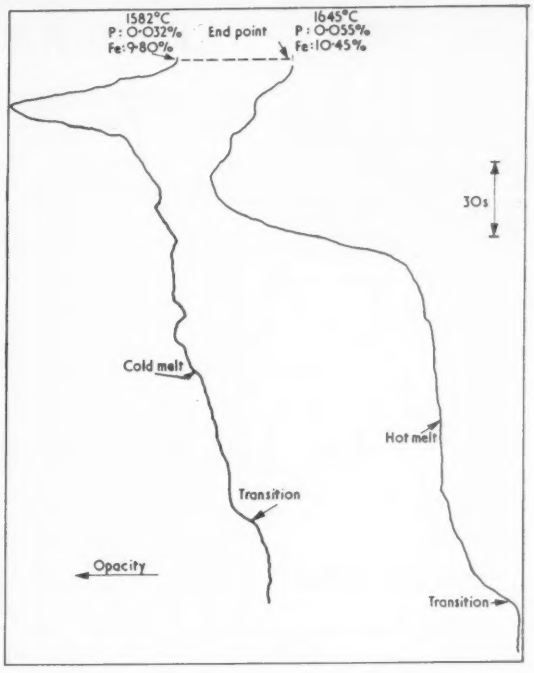


**Fig. 11—End-point basic Bessemer**

(*b*) to obtain, for daily production, more rigorous control of the blast and the temperature of heat, thereby to increase output, to lower the cost of production of steel, and to improve uniformity and quality of the finished product.

In addition to the immersion pyrometer, which is now a standard instrument, the aim was to supply industry with a set of new instruments, from among which each basic converter steelworks could choose those most suited to its special operating conditions.

The future will show how far these aims have been achieved.

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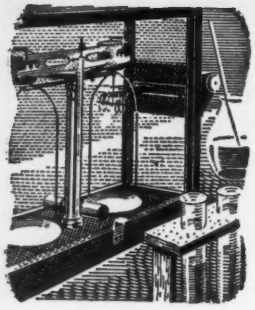

*PAPERS AND REPORTS ON RESEARCH AND PRACTICE*

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# An Analysis of the Available Data on the Total Heat of Commercial Steels

*By J. R. Pattison, B.Sc., D.I.C., Ph.D., A.Inst.P.*

SYNOPSIS

**The available sources of data on the total heats of commercial steels are given and an attempt is made to estimate their relative value. It is suggested that the most reliable data relate to a 4% silicon steel, which has been studied over a range of temperatures including the melting point. No other data for temperatures above 1300° C, for any steel, are yet available and the existing data for the range of temperatures up to 1300° C are of unproven reliability.**

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IN A PREVIOUS PAPER[1] a critical survey was made of the methods used in determining the total heats of iron and steel. In this survey, one of the conclusions reached was that further experimental work on the determination of the total heats of pure iron was necessary to clarify the position above 1400° C. The available published data on the total heats of various steels are very meagre and, here too, further work is necessary. To reduce the future experimental work to a minimum it is necessary to obtain the maximum information from the previously published figures, and for this reason the following analysis has been made of the available data on the total heats of steel.

## DATA FOR CARBON STEELS

The total heat of seven carbon steels between 0° and 650° C was measured by Oberhoffer and Meuthen[2] with an ice calorimeter. Umino[3, 4] measured the total heats of three carbon steels up to 300° C and the total heats of a different set of five steels in the $A_3$ region, with a water calorimeter. Investigations on a much larger scale had been previously carried out by Umino,[5] again by direct water calorimetry. The total heats of twelve different carbon steels were measured over the temperature range 0–1250° C.

The only other available data for carbon steels have been obtained by Baerlecken[6] over the temperature range 0–700° C and by experiments[7, 8] at the National Physical Laboratory, using indirect methods of measurement. These N.P.L. results, obtained by adiabatic calorimetry, have been combined and recalculated where necessary at B.I.S.R.A. and published as a whole.[9] The temperature range covered extends from 0° to 1300° C.

The N.P.L. and Umino data can be compared graphically in Fig. 1 where both sets are referred to the same datum level of zero total heat at 0° C. It is immediately clear that the two sets of curves are by no means in agreement and, further, that the curves drawn through the N.P.L. points must be treated with considerable reserve since they are too complex to be adequately defined by the plotted

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Dr. Pattison is in the Fuel Technology Section of the Association's Physics Department.

points. The maximum differences occurring between each of the pairs of curves range from 4% at 600° C to 9·6% at 1250° C, but are not simply correlated with temperature, for the maximum difference at 100° C is quite large (8·6%). The maximum difference does not occur at the same carbon content in each pair of curves. Whilst not in agreement with either set of data, the values of total heat obtained by Baerlecken,[6] using adiabatic calorimetry, support a linear relation between total heat and carbon content.

The complexity of the N.P.L. curves is magnified to some extent by the experimental method used to give direct measurements of true specific heats from which total heats were later obtained by integration, involving a summation of errors. For example, in Fig. 1 the pronounced kink in the curves from 900° to 1250° C at 0·415–0·435% carbon develops between 700° and 850° C and the difference between the total heat values at 1300° and 1000° C is 46·8 cal/g for 0·415% carbon and 46·6 cal/g for 0·435% carbon. The differences found in the region of the highest temperatures and lowest accuracy of Awbery and Snow's work are thus carried over by summation into Pallister's results, which were obtained at temperatures from 900° C upwards. However, this only illustrates the effects of the derivation of total heats by an indirect method and does not prove that the pronounced kink is due to an error in measurement.

A possible source of this kink at a carbon content of about 0·42% and at a temperature range of 700–800° C would be the discontinuity in the curve for the Curie temperature against carbon content which occurs in a similar position. However, if this was the explanation, a comparatively larger discontinuity in the slope of the total-heat/carbon-content curve would have been expected in the neighbourhood of the eutectic point at about 725° C and 0·87% carbon.

There is a possibility that the complexity of the N.P.L. curves may be unduly influenced by the variations in the other constituents of the steels, but this should also have affected Umino's curves. For instance, the N.P.L. steels with 0·415% and 0·435% carbon contained 0·11% and 0·20% silicon, respectively, and the steepest slope of the total-heat/carbon-content curves above 700° C occurs over this range. But Umino's steels with 0·30% and 0·54% carbon contained 0·22% and 0·12% silicon, respectively, without showing any change in the slope of the total-heat/carbon-content curve over the range.

If the constituents other than iron and carbon have a small influence on the total heat of a carbon steel, the steel could be assumed to consist of pure iron, carbon in solid solution, and cementite ($Fe_3C$). Further, if the Neumann[10]–Joule[11]–Kopp[12] law—that the molecular heat of a compound is equal to the sum of the atomic heats of its constituents—is assumed to hold, it follows that the total heat of a compound is equal to the sum of the total heats of each of its constituents multiplied by the proportional mass of that constituent in the compound. Applying this law to cementite, the relation between the total heat and the percentage of carbon in a steel would not be expected to be complex. However, the Neumann–Joule–Kopp law can be derived from the law of Dulong and Petit which only holds at high temperatures and therefore may not be applicable at the temperatures shown in Fig. 1.

The curves are too markedly different to enable any conclusions to be drawn about the relation between total heat and carbon content at any given temperature, but they may possibly give a measure of the total heat of pure iron by an extrapolation to zero carbon content. The values obtained by this procedure are given in Table I, and as a comparison the actual experimental values obtained by the same investigators with high-purity iron are also given.

This method of evaluating the total heat of iron from the values of total heat previously obtained for

## Table I

### TOTAL HEAT OF PURE IRON BY EXTRAPOLATION OF DATA ON CARBON STEELS

| Temperature, °C | Original Data from N.P.L. | | Original Data from Umino | | |
|---|---|---|---|---|---|
| | Total Heat of Pure Iron from Data on Carbon Steels,[9] cal/g | Total Heat of Pure Iron as Measured,[9] cal/g | Total Heat of Pure Iron from Data on Carbon Steels Obtained in 1926,[4] cal/g | Total Heat of Pure Iron as Measured in 1926,[13] cal/g | Total Heat of Pure Iron as Measured in 1929,[14] cal/g |
| 0 | 0 | 0 | 0 | 0 | |
| 100 | 11·4 | 11·2 | 11·1 (11·0) | 11·0 | |
| 200 | 23·6 | 23·2 | 22·5 (22·6) | 22·7 | |
| 300 | 36·8 | 36·0 | 34·9 (35·2) | 35·3 | |
| 400 | 50·7 | 49·7 | 48·8 (48·8) | 49·0 | |
| 500 | 65·7 | 64·8 | 63·1 (63·7) | 64·0 | |
| 600 | 83·6 | 81·8 | 80·7 (81·0) | 80·8 | |
| 700 | 104·4 | 100·8 | 100·0 (99·8) | 100·5 | 100·1 |
| 750 | 114·9 | 112·5 | 110·6 (111·0) | 112·1 | 109·0 |
| 800 | 121·4 | 123·4 | 126·2 (125·0) | 126·2 | 120·6 |
| 850 | 130·3 | 132·4 | 137·8 (138·8) | 139·8 | 130·1 |
| 900 | 140·7 | 140·9 | 153·3 (152·9) | 151·4 | 139·5 |
| 1000 | 158·8 | 158·9 | 169·7 (169·8) | | 161·3 |
| 1100 | 175·3 | 173·0 | 186·5 (186·9) | 186·9 | 177·8 |
| 1200 | 190·8 | 187·9 | 203·7 (203·5) | 203·5 | 194·8 |
| 1250 | 198·9 | 195·6 | 212·1 (212·2) | | |

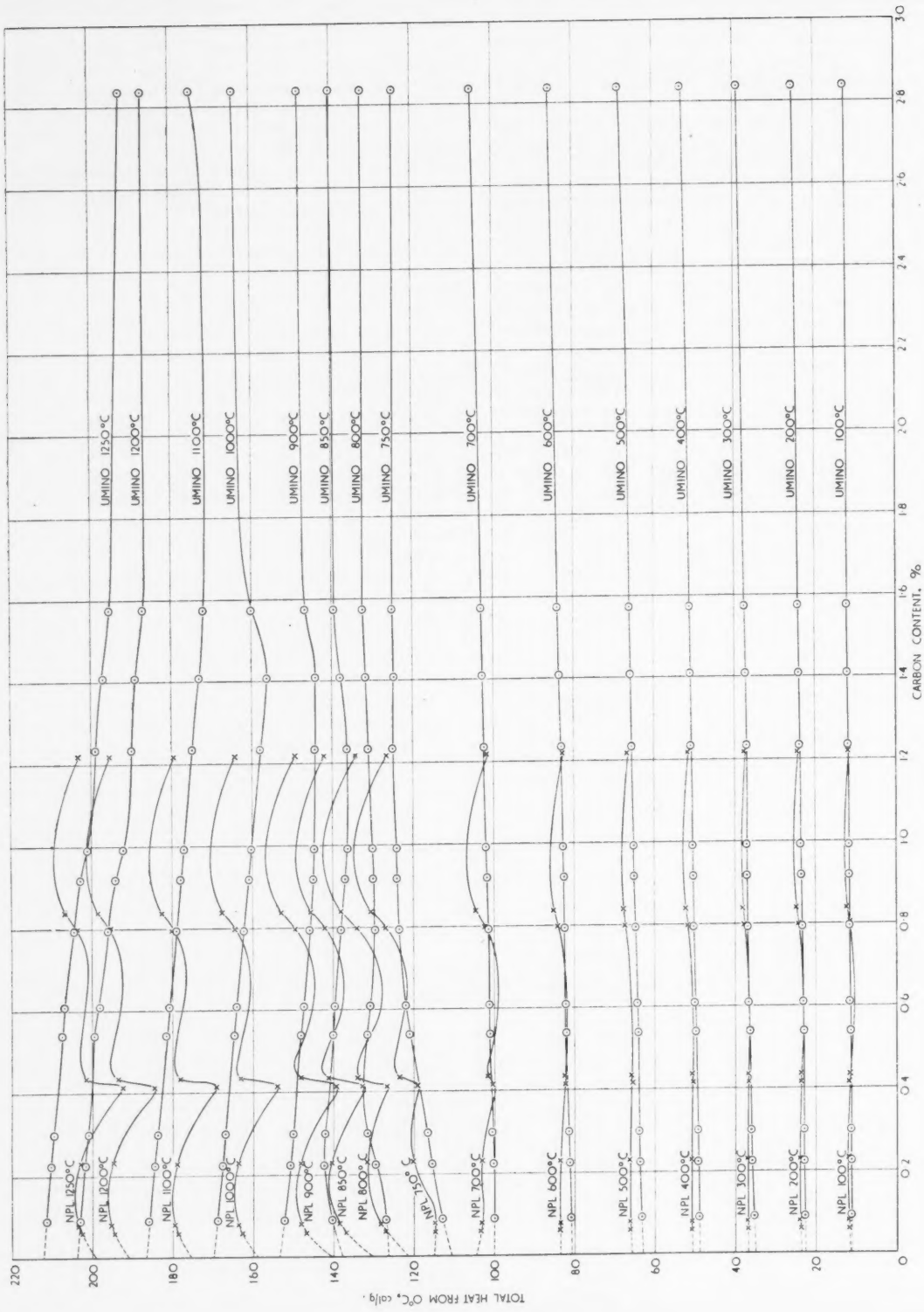


**Fig. 1—Total heat of carbon steels**

different carbon steels was used by Umino,[5] and his extrapolation results, as published, are given in brackets beside the values obtained from Fig. 1 of this paper. The disagreement between the two sets is nowhere as much as 1%. There have been no indications in print that the N.P.L. have attempted to derive values for the total heat of iron from curves relating total heat to carbon content; indeed, the shape of the curves is such as to make any interpolation or extrapolation dangerous. Nevertheless, the agreement between the values obtained by extrapolation and those obtained by direct measurement at the N.P.L. is quite good (especially so at 1000° C) and the greatest difference is about 3·4% occurring at 700° C. The agreement between the extrapolated and measured sets of data obtained by Umino in 1926 is even better and the greatest difference is about 1·4% at 500° C.

Unfortunately, the further measurements of the total heat of iron carried out by Umino[14] in 1929 must be assumed to be more reliable and replacing the previous measurements. The disagreement between the extrapolated values for 1926 and the directly measured values for 1929 is as much as 9% at 900° C.

Although there is an unsatisfactory agreement between the values obtained by Umino this does not necessarily mean that the relatively simple form of the curves of total heat against carbon content at various temperatures is impossible. However, the very complex form of the curves using the N.P.L. data make it impossible to differentiate between the two rival forms without further experimental investigation of a considerable number of different carbon steels.

No estimate of the accuracy levels of the published data is given by either the N.P.L. or Umino, so that it is not possible to determine where the two sets of data agree within the experimental limits.

### DATA FOR SILICON STEELS

The total heats of a steel containing 4·04% silicon, 0·04% carbon, 0·07% manganese, and 0·02% sulphur have been measured up to a temperature of 1560° C by Oberhoffer and Grosse.[15] Compared with the values obtained for iron containing 0·006% silicon, 0·02% carbon, and 0·004% sulphur by the same observers, there is very little difference at low temperatures but the difference increases with increase in temperature, until at 1452° C the total heat of the steel is 5% higher than that of the iron. In the steel the melting point occurs at 1488° instead of 1528° C and the latent heat of melting is 62·2 cal/g compared with 64·4 cal/g for the iron.

The only other available data for a silicon steel relate to a steel containing 0·49% carbon, 1·98% silicon, and 0·90% manganese investigated at the N.P.L.[9] up to 1300° C.

### ALLOY STEELS

The total heats of various low- and high-alloy steels have been measured up to 1300° C at the N.P.L. and the results collected and tabulated at B.I.S.R.A. have been published.[9] It is of interest to test the total heat form of the Neumann–Joule–Kopp law for alloys, by treating the metallic constituents of a steel as affecting the total heat of the whole in a purely additive fashion whereby a certain proportion by weight of iron is replaced by the same weight of another metal with a different total heat value. The metals investigated by Wüst, Meuthen, and Durrer[16] included manganese, chromium, nickel, tungsten,

Fig. 1—Total heat of carbon steels

## Table II

### THE DIFFERENCE BETWEEN THE TOTAL HEATS OF ALLOY STEELS AND OF IRON

| Steel Classification Number: | 13 | | 14 | | 15 | | 16 | | 17 | | 18 | | Total Heat of Pure Iron from 0° C, cal/g | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature, °C | Difference, cal/g | | Difference, cal/g | | Difference, cal/g | | Difference, cal/g | | Difference, cal/g | | Difference, cal/g | | Wüst, Meuthen, and Durrer[16] | N.P.L.[9] |
| | Calculated | Measured | Calculated | Measured | Calculated | Measured | Calculated | Measured | Calculated | Measured | Calculated | Measured | | |
| 100 | + 0·2 | + 1·2 | + 0·1 | + 0·8 | − 0·1 | + 1·0 | − 0·1 | 0 | − 0·1 | 0 | − 1·5 | − 1·4 | 11·11 | 11·2 |
| 200 | + 0·2 | + 2·4 | + 0·2 | + 1·1 | − 0·3 | + 1·7 | − 0·2 | + 0·2 | − 0·2 | 0 | − 2·0 | − 3·1 | 23·36 | 23·2 |
| 300 | + 0·3 | + 3·6 | 0 | + 1·2 | − 0·7 | + 1·9 | − 0·4 | + 0·3 | − 0·5 | + 0·1 | − 5·1 | − 4·9 | 36·75 | 36·0 |
| 400 | + 0·1 | + 4·4 | + 0·3 | + 0·5 | − 1·1 | + 1·6 | − 0·6 | + 0·7 | − 0·8 | + 0·3 | − 7·2 | − 6·8 | 51·27 | 49·7 |
| 500 | − 0·1 | + 4·0 | − 0·5 | − 1·3 | − 1·9 | + 0·6 | − 1·0 | + 1·4 | − 1·1 | + 0·9 | − 9·6 | − 9·1 | 66·94 | 64·8 |
| 600 | − 0·4 | + 3·7 | − 1·6 | − 4·4 | − 2·8 | − 1·1 | − 1·3 | + 2·4 | − 1·6 | + 1·8 | −12·2 | −12·0 | 83·74 | 81·8 |
| 700 | − 0·7 | 0 | − 3·1 | − 9·4 | − 4·0 | − 5·2 | − 1·8 | + 3·5 | − 3·1 | + 3·9 | −15·0 | −16·2 | 101·67 | 100·8 |
| 800 | − 1·8 | − 7·0 | − 6·3 | −17·9 | − 6·7 | −12·6 | − 2·9 | 0 | − 3·4 | + 2·6 | −19·1 | −21·5 | 125·73 | 123·4 |
| 900 | − 1·7 | − 8·7 | − 7·1 | −21·3 | − 7·0 | −14·7 | − 2·9 | + 0·1 | − 3·4 | + 4·4 | −21·5 | −22·1 | 141·65 | 140·9 |
| 1000 | − 2·3 | − 6·4 | − 9·6 | −20·8 | − 8·8 | −12·9 | − 3·6 | + 1·9 | − 4·2 | + 6·2 | −25·0 | −21·8 | 163·08 | 158·9 |
| 1100 | − 0·5 | − 4·2 | − 9·9 | −20·5 | − 8·4 | −11·3 | − 3·2 | + 3·4 | − 3·8 | + 7·5 | −27·1 | −21·2 | 177·56 | 173·0 |
| 1200 | + 1·6 | − 2·5 | −10·2 | −20·7 | − 7·8 | −10·2 | − 2·8 | + 4·0 | − 3·3 | + 8·2 | −28·7 | −21·5 | 192·05 | 187·9 |
| 1300 | ... | − 1·4 | −10·7 | −20·8 | − 7·3 | −19·7 | − 2·3 | + 3·9 | − 2·8 | + 8·5 | −30·6 | −22·7 | 206·53 | 203·6 |

**Table III**
**COMPOSITION OF THE STEELS**

| Number | C, % | Si, % | Mn, % | Cr, % | Ni, % | W, % | Mo, % | Cu, % | Al, % |
|---|---|---|---|---|---|---|---|---|---|
| 13 | 1·22 | 0·22 | 13·00 | 0·03 | 0·07 | Nil | Nil | 0·07 | Trace |
| 14 | 0·28 | 0·15 | 0·89 | Trace | 28·37 | Nil | Nil | 0·03 | 0·01 |
| 15 | 0·08 | 0·68 | 0·37 | 19·11 | 8·14 | 0·60 | Nil | 0·03 | Trace |
| 16 | 0·13 | 0·17 | 0·25 | 12·95 | 0·14 | Nil | Nil | 0·06 | 0·03 |
| 17 | 0·27 | 0·18 | 0·28 | 13·69 | 0·20 | 0·25 | 0·01 | 0·07 | 0·03 |
| 18 | 0·72 | 0·30 | 0·25 | 4·26 | 0·07 | 18·45 | Trace | 0·06 | Trace |

molybdenum, copper, and aluminium, as well as iron, so that these data may be used to calculate the effect of replacing iron by each of the other metals occurring in known proportions in an alloy steel. Table II gives, for comparison, the calculated change in the total heat of iron brought about by the metallic additions in different alloy steels using Wüst's data and also, from the N.P.L. data, the differences between the measured values of the total heats of each steel and the measured total heat of iron.

It is immediately apparent that it is impossible to evaluate the total heat of a given steel from the known values of the total heat of its metallic constituents. Only in the case of the high-speed steel (No. 18) up to 900° C is there any pronounced agreement between the calculated and measured differences of the total heats from those of iron, and this may be fortuitous, since the Neumann–Joule–Kopp Law would be more likely to hold at high rather than low temperatures.

## CONCLUSION

The available data for the total heats of any particular steel consist of either one set of figures which cannot be checked, or two sets of widely disagreeing values. On the evidence of the conflicting data, where such are available, it is apparent that no great reliance may be placed on the unchecked sets of data. Again, it is evident that little can be done in the way of evaluating the total heats for a given steel by the interpolation or extrapolation of the data available for other steels. The position is such that, except possibly in the case of the 4% silicon steel carefully studied by Oberhoffer and Grosse, the total heat of any steel cannot be estimated to an accuracy known to be better than 20%, up to 1300° C, without actually measuring it. Above 1300° C the only data available relate to the 4% silicon steel already mentioned so that, here again, direct measurement can be the only satisfactory source of information.

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# Thermodynamics of Carbon Dissolved in Iron Alloys

## Part V: SOLUBILITY OF GRAPHITE IN IRON–MANGANESE, IRON–COBALT, AND IRON–NICKEL MELTS

*By E. T. Turkdogan, R. A. Hancock, S. I. Herlitz, and J. Dentan*

SYNOPSIS

The solubility of graphite has been determined at temperatures up to 1550° C in iron–manganese, iron–cobalt, and iron–nickel melts over the entire composition ranges. It is found that manganese increases graphite solubility in iron whilst cobalt and nickel decrease it. In the case of iron–nickel melts at 1350° and 1550° C the solubility reaches a minimum value at about 80% nickel; reference is made to the anomalous behaviour of nickel in chromium–oxygen and iron–oxygen melts. The change of graphite solubility in iron on adding a second element $X$ is related to the atomic number, crystal radius, and second ionization potential of the element $X$.

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### Introduction

THE RESULTS of earlier work on the solubility of graphite in iron, iron–silicon, iron–phosphorus, iron–sulphur, and iron–silicon–phosphorus melts have recently been reported.[1, 2, 3] Apart from the work of Chipman *et al.*[4] on the solubility of graphite in iron–manganese melts, there are no reliable data on the solubility of graphite in binary melts of transitional elements. The purpose of this investigation was therefore to explore the variations in the solubility of graphite in such binary mixtures.

### EXPERIMENTS

The metals used in these experiments were pure manganese, iron, cobalt, and nickel. About 5 g of a mixture (iron–manganese, iron–cobalt, or iron–nickel) were packed in a small graphite crucible, 2 in. long, 0·4 in. bore, and 0·6 in. outside dia., which was fashioned from a graphite rod of high purity. The crucible was then placed in the hot zone of a vertical furnace fitted with a 1-in. dia. recrystallized alumina tube; depending on the temperature of the experiment, a platinum-wound or a molybdenum-wound furnace was used. Temperature measurements were taken with a Pt/Pt–13% Rh thermocouple in a thin-walled recrystallized alumina sheath; the top of the sheath was in close contact with the base of the graphite crucible. Preliminary measurements indicated that the melt was within the uniform temperature zone of the furnace, and that temperature readings at the base of the crucible were the same as those taken by a second thermocouple immersed temporarily in the melt. An automatic ON–OFF controller maintained the temperature of the furnace well within ± 2° C of the required level.

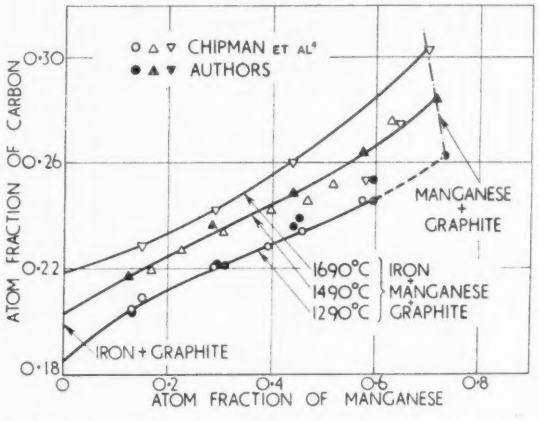


**Fig. 1—Solubility of graphite in iron–manganese melts**

In order to avoid the oxidation of the metal and crucible, the experiments were conducted in oxygen-free dry nitrogen. At the end of the experiment the crucible was rapidly withdrawn from the reaction tube by means of a molybdenum wire and quenched in water. Traces of free graphite adhering to the surface of the metal were removed by grinding and rubbing with a fine emery cloth. The specimens were then reduced to a fine granular state in a percussion mortar.

The carbon contents of the samples were determined by the combustion method, agreement between duplicates being within ± 0·01%. The iron was analysed by the stannous chloride method and the estimations were reproducible to within ± 0·05%. Cobalt and nickel do not interfere with the iron determinations but, in the case of iron–manganese samples, the latter element was removed by precipitating iron from the solution in sulphuric acid as ferric hydroxide which after filtering was dissolved in 1 : 1 hydrochloric acid, and from this stage onwards the stannous chloride method was followed.

As stated in a previous part of this series,[1] saturation with graphite is attained within 1 h of the commencement of an experiment; in all the present

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Dr. Turkdogan is Head of the Physical Chemistry Section of the Chemistry Department of B.I.S.R.A., and Mr. Hancock is with this section. Mr. Herlitz and Mr. Dentan were with the Association as vacation students from the Royal Institute of Technology, Stockholm, and l'École Polytechnique de l'Université de Lausanne, respectively.

runs 2 h were allowed for the establishment of equilibrium between the binary metal solution and the graphite crucible.

## RESULTS AND DISCUSSIONS

The experimental results are given in Table I*a–c*. As seen from Fig. 1, where the solubility of graphite in terms of atom fraction is plotted against the manganese content of the melts, the present results generally agree with those of Chipman *et al.*[4]

The solubility of graphite in molten manganese, cobalt, and nickel has recently been determined by the authors.[5] The following expressions give the temperature dependence of graphite solubility in

(*a*) Manganese

$$\log N_C = -\frac{460}{T} - 0{\cdot}285 \quad \text{.....(1)}$$

(*b*) Cobalt

$$\log N_C = -\frac{1050}{T} - 0{\cdot}265 \quad \text{.....(2)}$$

(*c*) Nickel

$$\log N_C = -\frac{1820}{T} + 0{\cdot}097 \quad \text{.....(3)}$$

where $N_C$ is the atom fraction of carbon. A similar expression for carbon solubility in iron based on all available data was given in Part I,[1] thus:

$$\log N_C = -\frac{560}{T} - 0{\cdot}375 \quad \text{.....(4)}$$

The extreme ends of the curves in Fig. 1 are calculated from equations (1) and (4). It is to be noted that the relationships in Fig. 1 are more complex than those found in the cases of carbon in iron–silicon, iron–phosphorus, and iron–sulphur melts.[1, 2] At low manganese concentrations the slopes of the curves decrease with increasing temperature while at

**Table I**

**SOLUBILITY OF GRAPHITE IN IRON–MANGANESE, IRON–COBALT, AND IRON–NICKEL MELTS**

| Melt | No. | Weight, % | | Atom Fraction | |
|---|---|---|---|---|---|
| | | Fe | C | Fe | C |
| (a) Fe–Mn at 1290° C | A 1 | 0 | 7·25 | 0 | 0·2636[a] |
| | 2 | 19·4 | 6·89 | 0·154 | 0·254 |
| | 3 | 19·9 | 6·62 | 0·159 | 0·246 |
| | 4 | 38·3 | 6·39 | 0·308 | 0·239 |
| | 5 | 39·9 | 6·29 | 0·442 | 0·236 |
| | 6 | 57·1 | 5·79 | 0·469 | 0·221 |
| | 7 | 58·7 | 5·81 | 0·482 | 0·222 |
| | 8 | 79·1 | 5·21 | 0·663 | 0·203 |
| | 9 | 79·2 | 5·24 | 0·663 | 0·204 |
| | 10 | 95·36 | 4·64 | 0·8151 | 0·184[b] |
| at 1490° C | A 11 | 0 | 7·98 | 0 | 0·2844[a] |
| | 12 | 19·0 | 7·23 | 0·149 | 0·264 |
| | 13 | 39·0 | 6·69 | 0·311 | 0·248 |
| | 14 | 58·7 | 6·28 | 0·475 | 0·237 |
| | 15 | 79·4 | 5·65 | 0·657 | 0·218 |
| | 16 | 94·82 | 5·18 | 0·7972 | 0·2028[b] |
| (b) Fe–Co at 1350° C | B 1 | 0 | 2·76 | 0 | 0·122[c] |
| | 2 | 20·3 | 2·95 | 0·190 | 0·129 |
| | 3 | 39·0 | 3·33 | 0·357 | 0·142 |
| | 4 | 74·0 | 4·17 | 0·649 | 0·170 |
| | 5 | 95·19 | 4·81 | 0·8095 | 0·1905[b] |
| at 1550° C | B 6 | 0 | 3·32 | 0 | 0·144[c] |
| | 7 | 22·7 | 3·63 | 0·208 | 0·154 |
| | 8 | 47·8 | 4·23 | 0·424 | 0·175 |
| | 9 | 72·0 | 4·71 | 0·621 | 0·189 |
| | 10 | 94·66 | 5·34 | 0·7920 | 0·2080[b] |
| (c) Fe–Ni at 1350° C | C 1 | 0 | 2·09 | 0 | 0·095[d] |
| | 2 | 10·2 | 1·75 | 0·100 | 0·080 |
| | 3 | 19·5 | 1·54 | 0·192 | 0·070 |
| | 4 | 30·3 | 1·80 | 0·293 | 0·081 |
| | 5 | 42·3 | 2·45 | 0·398 | 0·107 |
| | 6 | 72·3 | 3·59 | 0·646 | 0·149 |
| at 1550° C | C 7 | 0 | 2·85 | 0 | 0·126[d] |
| | 8 | 10·5 | 2·40 | 0·101 | 0·107 |
| | 9 | 21·8 | 2·43 | 0·207 | 0·108 |
| | 10 | 43·4 | 3·15 | 0·398 | 0·135 |
| | 11 | 71·0 | 4·10 | 0·624 | 0·168 |

*a*: The solubility of graphite in pure manganese
*b*: The solubility of graphite in pure iron
*c*: The solubility of graphite in pure cobalt
*d*: The solubility of graphite in pure nickel

**Table II**

**COMPARISON OF DATA ON THE SOLUBILITY OF GRAPHITE IN IRON–NICKEL MELTS**

| Temp., ° C | Ni, % | C, % | Reference |
|---|---|---|---|
| 1350 | 21·9 | 3·73 | Schichtel and Piwowarsky[6] |
| 1550 | 21·9 | 4·24 | |
| 1350 | 27·9 | 3·50 | |
| 1550 | 27·9 | 4·05 | |
| 1350 | 24·1 | 3·59 | Present Work |
| 1550 | 24·9 | 4·10 | |

high manganese concentrations the slopes increase with temperature.

It should be noted that although the solidification temperature of carbon-saturated pure manganese, according to the authors' recent work,[5] is 1380° C (presumably a peritectic invariant), in the presence of iron the solidus temperature is somewhat lowered. The curve for 1290° C in Fig. 1 is drawn in broken lines near the manganese/graphite boundary and the saturation point given is that of a supercooled melt.

The results in Table I*b* are plotted in Fig. 2 as $N_C$ against $N_{Co}$. As indicated by equations (2) and (4), the temperature coefficient of carbon solubility in cobalt is greater than that in iron and the smooth curves in Fig. 2 indicate that, for a given cobalt content, the rate of decrease of solubility of carbon becomes greater as the temperature is lowered.

Figure 3 illustrates the reduction in the solubility of graphite in iron by nickel at 1350° and 1550° C. Schichtel and Piwowarsky[6] studied the effect of nickel on the solubility of graphite in iron. The values in Table II are taken from their graph for 21·9% and 27·9% nickel for comparison with the present results. Linear interpolation of the results of Schichtel and Piwowarsky gives 3·64% and 4·14% as the carbon solubility in iron–nickel alloys containing 24·1% and 24·9% nickel at 1350° and 1550° C. These values compare well with those obtained in the present work. The solubility of graphite in iron–nickel alloys reaches a minimum at about 0·75 atom fraction of nickel, i.e. at about 80% nickel, then the carbon solubility increases. This anomalous property

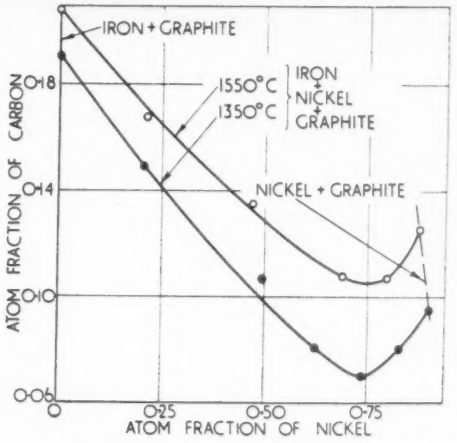


**Fig. 3—Solubility of graphite in iron–nickel melts**

of nickel has been observed in other systems: e.g., according to Bezobrazov and Samarin[7] the solubility of oxygen in chromium–nickel melts decreases with increase in the concentration of nickel; above 90% nickel, however, there is a slight increase in the solubility of oxygen. Similarly, it has been shown by Wriedt and Chipman[8] that the solubility of oxygen in iron–nickel decreases slightly with increase in the concentration of nickel up to about 90%, then further increase in the percentage of nickel raises the oxygen solubility. On the contrary, the results of Cordier and Chipman[9] on the activity of sulphur in iron–nickel melts indicate that the chemical behaviour of sulphur in these alloys is not affected by nickel. Sudden increase in oxygen solubility in nickel-rich side of the chromium–nickel and iron–nickel alloys may, however, be attributed to an increase in the oxygen potential of the oxide slag which becomes enriched in nickel oxide when chromium or iron contains more than about 80% nickel.

Although the molten alloys of manganese, cobalt, and nickel with iron are known to be ideal solutions,[10–14] it is interesting to note that the behaviour of these transitional elements towards a solute in iron differs considerably. Although it is not at present possible to offer a theoretical explanation for the observed effects of various elements on the solubility

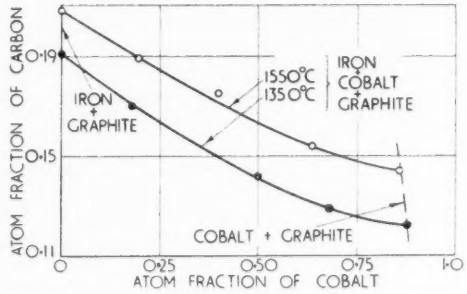


**Fig. 2—Solubility of graphite in iron–cobalt melts**

**Table III**

**CHANGE IN THE SOLUBILITY OF GRAPHITE IN MOLTEN IRON WITH ADDITION OF A SECOND ALLOYING ELEMENT**

| Added Element | $\delta \Delta N_C^X / \delta N_X$ | Reference |
|---|---|---|
| Al | −0·50 | 15 |
| Si | −0·71 | 1 |
| P | −0·84 | 1 |
| S | −1·0 | 2 |
| Mn | +0·1 | Present Work |
| Co | −0·1 | ,, |
| Ni | −0·2 | ,, |

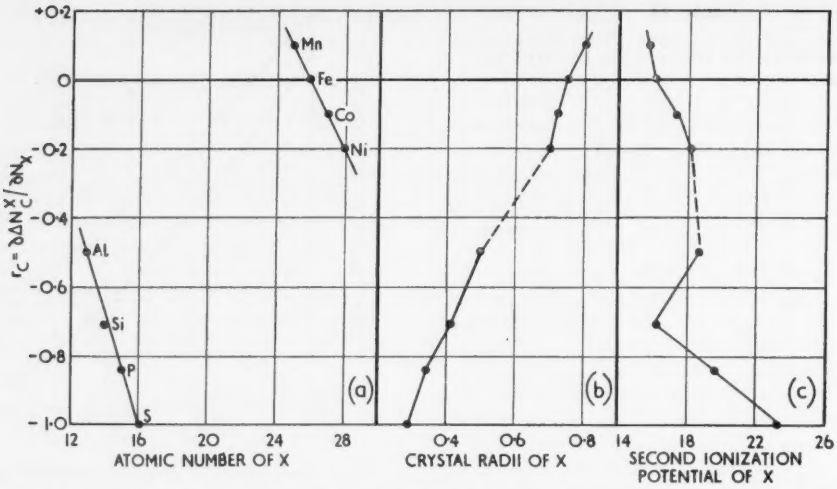


**Fig. 4—Effect of solute *X* on the solubility of graphite in molten iron related to some properties of element *X***

or activity of carbon dissolved in iron, the following empirical relationships are worthwhile mentioning.

If $N_C$ and $N_C^C$ are chosen to represent concentrations of carbon at saturation in iron–$X$ and pure iron melts, then the difference

$$\Delta N_C^X = N_C - N_C^C \quad \ldots\ldots(5)$$

gives the change in graphite solubility in iron when an element $X$ is introduced into the system at the same temperature. It was shown by Turkdogan and Leake[1] that $\Delta N_C^{Si}$ and $\Delta N_C^P$ are continuous functions of silicon and phosphorus concentrations and independent of temperature. Although in the systems studied in this work (i.e. where $X$ is a transitional element) equation (5) is dependent on temperature, at low concentrations of $X$, the effect of temperature is slight, as is seen from Figs. 1, 2, and 3; furthermore, the relationship between $\Delta N_C^X$ and $N_X$, where $N_X$ is the atom fraction of $X$, can be considered linear in dilute solutions. The rate of change of graphite solubility on adding a second element may be represented by $r_C = \delta\Delta N_C^X/\delta N_X$, the values of which are given in Table III for various alloys.

As indicated by Fig. 4*a*, the value of $r_C$ decreases linearly as the atomic number of the element $X$ increases in a given period of the Periodic Table. The lines for the Second Short and First Long Periods are well apart from one another.

Figure 4*b* shows an interesting relationship where $r_C$ decreases with the empirical crystal radii[16] of the elements in the free state. This may be due to the fact that as an element $X$ of crystal radii smaller than that of iron replaces the latter element, the size of the interstitial sites becomes smaller and hence results in the reduction of graphite solubility.

In the recent paper dealing with the solubility of graphite in pure transitional elements the authors[5] indicated that the solubility of graphite decreases as the second ionization potential of the solvent element increases. An analogous relationship is shown in Fig. 4*c* where $r_C$ is plotted against the second ionization potential[17] of the element $X$ added to iron. Although the point for silicon disrupts the continuity of this relationship, it appears that in Fe–$X$ melts, the solubility of carbon for a given concentration of $X$ decreases as the second ionization potential of the element $X$ increases.

## Acknowledgment

The authors wish to express their thanks to Dr. J. Pearson for the interest he has shown in this work.

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# *DISCUSSION ON PAPERS*

**Discussion at Meetings · Written Contributions**

# Special Meeting in Scunthorpe, 1955

A SPECIAL MEETING of The Iron and Steel Institute was held in Scunthorpe from Wednesday 12th to Friday 14th October, 1955, by invitation of the President and Council of the Lincolnshire Iron and Steel Institute. A report of the Meeting was published in the January, 1956, issue of the *Journal* (pp. 1–2). A report of the discussions at the three technical sessions, at which six papers were presented, is given below.

## UNDERGROUND MINING AT DRAGONBY

Mr. **C. Smith** (United Steel Companies Ltd., Ore Mining Branch) presented his paper on " Underground Mining of the Frodingham Ironstone Bed at the Dragonby Mine, Scunthorpe " (*J. Iron Steel Inst.*, 1955, vol. 181, Oct., pp. 150–158).

Mr. **G. H. Johnson** (The Kettering Iron and Coal Company Ltd.): Mr. Clifford Smith has given us a clear picture of the pioneering work undertaken in the mining of the Frodingham bed to preserve the continuity of a proved advantageous balance between the limey Lincolnshire ironstone and the siliceous Northamptonshire as required in such vast quantities at his Company's ironworks.

I accept without question that recourse to the underground method of extraction in the Dragonby area was dictated by the fact that, as the workings are driven forward in an easterly direction following the general dip of the bed, the depth of cover increases to a thickness impracticable for the opencast working which has obtained in north Lincolnshire for many years—and has been increasingly used recently.

Mining engineers try to draw fine distinctions between what constitutes a quarrying and what a mining proposition in our indigenous stratified ironstone, but each case must be considered, after comprehensive prospecting and boring. In Northamptonshire, under suitable conditions, stripping machines have been developed over relatively few years which transform what were formerly regarded as mining propositions into opencast workings, with 100% extraction of the ironstone.

However, in view of the probable shrinkage of the scale of opencast production in the foreseeable near future, the need at least to maintain overall output if not considerably to expand it, and the long time taken to develop a mine as exemplified in the case under review, there is a need for further ventures of this kind in other parts of the home ironstone fields, particularly in the area north of the Welland. Since conditions in different parts vary so widely, the best methods of operation can only be decided by experience.

We would all like to know what actual percentage of the bed will eventually be recovered in what are essentially mining propositions, Dragonby included, for obviously the working methods employed must aim at the maximum recovery consistent with safety and cost, coupled with the minimum of surface damage, although I believe that the sands and clays in the Frodingham area are not generally overlaid by such agriculturally valuable soil as in certain other areas. We are acquiring the ' know-how ' and we have the technicians to develop production from below ground, but in view of the great scarcity of labour and the increase in the ratio of manpower to production required for mining operations, particularly where the seams are thinner than in the exceptionally thick Frodingham bed, one of the problems facing producers from below ground is likely to be a shortage of personnel. Highly mechanized mining is a specialized job requiring trained personnel, and there is a disinclination to-day to enter the mining industry, due partly to the unpleasant history of human relations and the arduousness and comparative dangers and hazards of the industry, as compared with opencast quarrying and other more congenial occupations. Dragonby Mine is planned eventually to produce by stages one million tons of ironstone per annum, and to keep manpower to a minimum it has been mechanized to the fullest possible extent.

Mr. **T. M. Dover** (The United Steel Companies, Ltd., Ore Mining Branch): Under the heading " Ore Production Policy " Mr. Smith mentions the extensive prospecting that was carried out and has provided an accurate picture of the geological and structural position of the bed. Until recently, few mining companies were prepared to spend money on adequate prospecting.

In his introduction Mr. Smith states that the opencast faces advancing " eastwards with the general dip of the bed and against sharply rising surface contours, are meeting such thicknesses of overburden as will eventually make them either uneconomical or impracticable, or both." He says that " No one can at present say definitely where this limit will be."

I suggest that the limit of opencast mining is entirely economic. The advent of scrapers drawn by wheeled and caterpillar tractors has completely revolutionized opencast working, and practicability is an almost impossible term to define since the length of haul is only limited by economic considerations. Mr. Smith states under the heading " Area and Site " that an area was chosen which, because of its depth, could not be worked by opencast mining. These two statements are contradictory. The economic considerations which limit opencast working are very difficult to formulate and it will be necessary to consider such points as the loss of ore reserves in roof and pillars, and the effect of lower iron-content furnace burdens on coke consumption, furnace capacity, slag disposal, etc., due to the leaving of 12 ft 6 in. of the highest iron-content stone in the roof, as shown in Fig. 4.

It has been suggested that opencast working with very deep overburden could not be contemplated because of the difficulty of restoration. The experimental plot operated by the Ministry of Agriculture at Roxby has shown that better crops can be grown on restored lias clay overburden than on the original sand surface in the Frodingham district. The lower output per man obtained when working underground is also serious if very large quantities are to be obtained by this method. Under " Manpower and Outputs " Mr. Smith shows that 10,000 tons/week can be expected with 120 men, an output of 84 tons/man-week. The comparable figure for opencast work is about 140 tons/man-week. As to the consumption of explosives, underground 1 lb of explosives produces 1·4 tons of broken ore; by opencast 1 lb of explosives produces 4–6 tons of ore.

What is the future system of pillar extraction likely to be? In the Cleveland bed the formation of pillars was completed through the whole area before systematic robbery began, resulting in the leaving of a bed of ore similar in texture to a piece of worm-eaten wood with the problem of working through collapsed roadways to reach most of the pillars to be extracted. It is hoped that this will not be repeated in the Frodingham bed with the consequent heavy loss of ore to the nation.

Has Mr. Smith tried a wedge cut at right angles to that shown, i.e. with the holes cutting the strata so that the planes of weakness will assist the breakage?

Mr. **L. Highton** (The Beckermet Mining Company Ltd.): In 1929 the late Mr. J. Henderson asked me to make proposals for working the Frodingham ironstone bed underground. At that time we did not have the present mechanical means of operating underground, and so my proposal, whilst in general outline somewhat similar, provided for greater entry into the bed.

Would Mr. Smith say how he proposes to remove the ore when he has completed his first working?

The method of taking the ore away from the face is not perfect. It is loaded with a machine, developed for working with soft coal in America. It is then loaded into a shuttle car giving 17 tons/man-shift. One U.K. mine is getting 25 tons/man-shift, using a form of shovel loader and a Euclid truck. The Joy loader and the shuttle car are expensive to maintain. This is perhaps a result of bringing the coal-cutting machine into an iron mine.

At Dragonby, there is a relatively flat bed, all the money one requires, and relatively few underground difficulties; the difficulties come when robbery starts. Are the beds over this seam heavily charged with water? Can the whole output be taken without affecting the water supply of this area?

## CORRESPONDENCE

Mr. **R. J. M. Dixie** (Ore Mining Branch, United Steel Companies Ltd.) wrote: Underground mining of the bedded iron-ores of Great Britain will become of increasing importance in the future as the outcrop and sub-outcrop areas are worked out.

It is essential now, when practically the whole of our ore supplies are being obtained from opencast mines, that adequate data on methods, machines, cost etc. are obtained by the development and operation of an underground mine. This paper suggests that the Dragonby Mine will go far in providing this information so far as the Frodingham Bed is concerned.

In recent years great progress has been made in opencast mining practice, particularly in the development of large strippers and other rugged types of earth-moving equipment, which will enable greater thicknesses of overburden to be moved more economically than has been possible in the past. I suggest therefore that before deciding to use opencast or underground mining methods for any given mining area the following points must be considered.

(i) The cost per ton of winning the ore.
(ii) The possible " recovery " of the ore both as to tonnage and units of iron.
(iii) The condition of the surface after the mining operations have been completed.

There are one or two details in Mr. Smith's paper that call for comment.

The Frodingham Bed is markedly lenticular in a strike direction, i.e. north to south; in the dip direction i.e. west to east, this lenticularity is not so marked, and thinning of the Bed at or near its western outcrop is an erosional and not a depositional feature.

The dip section of the Bed shown in Fig. 2 illustrates very clearly that for a considerable distance down dip, to the north of the Flixborough–Appleby faulting, the cover does not increase appreciably.

The adoption of electrically powered and hydraulically-operated rotary drilling units is of great interest as this is a parallel development to opencast mine practice. In the latter case the rotary units have proved greatly superior to the compressed air percussive units previously used, and it would appear from this paper that similar advantages are being obtained underground.

It is appreciated that the Coal Mines Act does not encourage the use of diesel engines underground, but the underground tunnels at this mine are of very generous dimensions, and there would appear to be possibilities for developing a small type of digger loading into wheeled trucks for transport to the conveyors, rather than to use machinery which although it has been well adapted for hard rock use is still essentially coal-mine machinery.

## AUTHOR'S REPLY

Mr. **C. Smith**: I should like to thank those who have contributed to the discussion, for the reception given to the paper, and comment on the various points raised.

I agree with Mr. Johnson in his statement, " that in widely varying conditions the best methods of operation can only be decided by experience." This is what we are endeavouring to do at Dragonby.

The percentage of the bed which will be worked can only be ascertained in the future after sufficient trials have been made by various methods of working, to find that best suited for and allowing the maximum extraction of the main panels. This will not necessarily be the present methods described in the paper, which are for driving main developing headings. It is confidently expected that the O.M.S. obtained during the extraction of panels will be greater than at present, particularly if ' loose-end ' working can be achieved. This, to some extent, will assist in the manpower required.

I cannot share some of Mr. Dover's views. He states that " the advent of scrapers drawn by wheeled and caterpillar tractors has completely revolutionized opencast working." This is possibly true, but until the present time no one in the Scunthorpe district, where the overburden consists of Lias clay, has removed anything like 250 ft of overburden. It is worth noting that the underground mines have been sited so that they will not interfere seriously with future opencast mining, even if this is found possible with overburden up to the thickness mentioned by Mr. Dover.

The " loss of ore reserves in the roof and pillars and the effect of lower iron content " etc. is something which will have to be proved by future workings. The fact that 12 ft 6 in. of the bed is now left intact does not in any way mean that it will be left up over the vast area to be worked. It is left now because it is considered that the dimensions of the present roadways are about the maximum which can be taken in one operation and are, as stated in the paper, the main arterial roadways of the Mine. The methods used for the driving of these roads may not be used for extracting the panels and the proportion of the total seam which will be extracted is a matter for future experience.

The comparisons made by Mr. Dover of the outputs per man-week and the amount of explosives used are meaningless during the present stages of development. Where tunnelling out of the solid mass is a necessary feature, the blast pattern is designed to produce a roadway to the shape and dimensions required, with a minimum of after-trimming. I suggest that this is materially different from blasting an open quarry face.

I am afraid I have not had any experience of the working of pillars in the Cleveland district, so I would prefer not to offer any observations thereon.

Concerning the shot-hole pattern, various forms of ' wedge-cut ' have been tried, but none of these were as successful as the method described. One disadvantage to wedge-cuts is that the majority of the holes drilled are on different ' rakes ' or angles, which brings in the human element of the driller far more than does a number of parallel holes. Another disadvantage is in the amount of fly-rock which is projected during blasting for considerable distances from the face; at present the blast pile drops within 20 ft of the working face.

Mr. Highton's remarks are noted with interest. We are proud to be associated in the development of a project in which he himself was interested nearly 30 years ago.

Concerning the removal of the ore when the first workings have been completed, I cannot go further at present than to say it will probably be by some method of " loose-end " work, using such machines as Duckbill loaders working on various horizons within the bed itself. It is envisaged that such machines could deliver the broken ore direct on to the trunk conveyor system without any intermediate vehicular transport. The method of work may call for some back-filling of certain areas as and when extracted.

On the question of water, the overlying beds are not so heavily charged as to prevent the whole area being worked out, should that be possible.

Mr. Dixie in his written contribution rightly draws attention to points requiring major consideration before starting an underground mine or mines. Dragonby Mine will help to provide the answers to these when considering other areas which will have to be worked by either one method or the other.

I thank Mr. Dixie for pointing out that the Frodingham Bed is markedly lenticular in a strike direction, but that from west to east it is not so marked and that the thinning at or near its western edge was due to erosion. As Mr. Dixie is a geologist, I accept his better description. I got the erosional edge correct but omitted to refer to the depositional.

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## IRONMAKING AT APPLEBY-FRODINGHAM

Mr. **G. D. Elliot,** O.B.E. (Appleby-Frodingham Steel Company) introduced his paper " Developments in Ironmaking at Appleby-Frodingham " (*J. Iron Steel Inst.*, 1955, vol. 181, Sept., pp. 1–16). He pointed out the following errors in the paper as printed: Figure 8 was printed upside down, and the last sentence of the paragraph entitled " Conclusion " (p. 16) should read: " The problems associated with smelting *sinter* are, in the main, quite different from the problems associated with smelting British carbonate ores."

Mr. **James Mitchell,** C.B.E. (Stewarts and Lloyds Ltd.): It is rather a pity that Table I gives no indication of slag quantities. Table II shows the deterioration of the ores themselves, although in practice this may well have been much more serious than the figures suggest. Finally, the table of heat balances (Table IV) is misleading, because the total B.t.u's shown there is not the total needed to produce a ton of pig iron; it is merely what is needed to produce a ton of pig iron from Appleby-Frodingham sinter, which is quite different. It would

help very much to know the total B.t.u's on the drying plant and the sinter plant per ton of iron. The figure is doubtless quite favourable and there is still a very considerable gross saving, but the total should either be replaced or accompanied by a table showing the total balances from the rock ore out of the quarry to the pig iron.

One would like to know much more definitely than is set out in the paper whether the right way to handle the lump ore part of this burden is, in fact, to crush it fine and sinter it. As a believer in the future of calcination, I think a burden consisting of sintered fines plus calcined lump would probably be just as economic and give equally spectacular results. Not all the knowledge required to do this is available at the moment; a method of getting rid of sulphur in the calcination plant still awaits discovery. It may also be said that calcination will increase the dust content, but surely this could be trapped and sent to the sinter mixture as is done at present with returned fines.

The treatment adopted for lower-grade ores depends on what one can afford to pay, and the process used should be that which gives the lowest final pig-iron cost. It does not follow that the method advocated in this paper is necessarily the best for other low-grade ores.

Mr. **R. P. Towndrow** (Colvilles Ltd.): Mr. Elliot gives us leave to assume that what might be right for Appleby-Frodingham is not necessarily right for Glasgow or South Wales. He says that in smelting an ore burden uniform stock descent may still be a very good thing, and I should like him to elaborate a little upon that subject.

Many of us are persevering in the better preparation of ores from a physical point of view. Mr. Elliot, however, having decided that it is not worth while to try to screen properly the very difficult ores of this district, has turned them all fine and made sinter out of them.

Mr. Mitchell pointed out the economic considerations that must be borne in mind in this matter, but he did not say that in addition to the dearer cost of carrying out the ore preparation programme the margin for a possible improvement, existing in an established practice, must be considered. The theoretical minimum carbon consumption of a blast-furnace has been argued. Colclough put it at about 1200 lb of carbon per ton of pig iron. Some do it for about 1350 lb and many are able to do so for 1600 lb. Mr. Elliot now does it for about 1750 lb.

It is perhaps not altogether wrong to think that improvements are possible in existing practice by examining the practice of screening and sintering both at once, rather than sintering everything.

Dr. **J. H. Chesters** (United Steel Companies Ltd.): Does Mr. Elliot think that a 30-ft diameter is really the extreme size for a blast-furnace? Is there any reason to believe that a move from 30 to 32 ft would not yield an improvement?

During the last 10 years production at Appleby-Frodingham has increased rapidly. A furnace intended two or three years ago to make not even 7000 tons per week is now driven to produce as much as 11,200 tons in one week. That makes me apprehensive about refractories. Does not Mr. Elliot think that even his carbon hearth might break down with such production? Is there any warning of a possible breakdown? Does the iron or slag temperature tend to go up when a furnace is driven at these fast rates?

**Sir Charles Goodeve,** O.B.E., F.R.S. (British Iron and Steel Research Association) asked about latest production figures from Appleby-Frodingham.

Lt.-Commander **G. W. Wells:** The only statement in the general press is that Queen Victoria Furnace made 11,160 tons in a period of seven days. It made 9,800 last week—and has not gone out. (*see J. Iron Steel Inst.*, 1955, vol. 181, Dec., p. 315).

**Sir Charles Goodeve:** How does the ore get into the top of the blast-furnace at the quoted rate? When a blast-furnace is built it is given a certain amount of equipment and capacity for loading and taking away all the things that come out. In the original furnace an over-large capacity in charging equipment must have been installed, in anticipation of what Mr. Elliot and his colleagues were going to do. If not, how has Mr. Elliot solved all the handling problems? I suspect that the original designers had a lot of foresight.

Major **W. R. Brown** (Ashmore, Benson, Pease and Co.): I recall the B.I.S.R.A. blast-furnace conference in 1952, when Sir Charles Goodeve challenged furnace operators to produce 10% more iron, in order to make further imports unnecessary. The response was not encouraging until Mr. Elliot gave figures showing how outputs were increasing at Appleby-Frodingham and boldly gave promise of greater things to come. He has fulfilled that promise magnificently.

At the same conference Mr. Elliot expressed his dislike of engineers. Would he not revise that opinion now, for his achievements owe much to those he maligned? Though his plant was designed to blow a nominal 80,000 ft³/min, he has not been limited by the charging equipment, the gas cleaning plant, or by anything else, even when driving at 130,000 ft³/min. Engineers have truly served him well.

Mr. **J. Evans** (John Summers and Sons Ltd.): With regard to the ever-increasing tonnages on blast-furnaces, would Mr. Elliot state what might be the ultimate limiting factor on output? For instance, would it be furnace throughput time, economics, or even slag disposal, having in mind the fast furnace driving rate and high slag/iron ratio at Appleby-Frodingham, besides the use of ladles for disposal?

Mr. Towndrow has mentioned the current success of bosh tuyeres at Appleby-Frodingham, a practice previously condemned by the present advocates. I think it has to be appreciated that they are now employed on furnaces of modern lines, with lower boshes, and in particular, charging fully prepared home burdens. Perhaps Mr. Elliot would like to express his views regarding the use of bosh tuyeres for furnaces charging semi-prepared burdens, and also for furnaces charging prepared 100% foreign ore burdens.

Mr. **A. Bridge** (Appleby-Frodingham Steel Company): The charging equipment and auxiliary plant have served us very well. That is due to the fact that Mr. Elliot and the Appleby-Frodingham design department—together with Ashmores and other contractors—have shown considerable foresight in keeping something in reserve, on the furnace side. At present we have four furnaces and only four turbo-blowers, and as Queen Victoria furnace is served by two turbo-blowers, the gas-engine blowers are retained to blow one of the smaller furnaces.

## CORRESPONDENCE

Mr. **A. P. Greenough** (University College, Swansea) wrote: The improvement in the coke rate and productivity since 1944, despite the deterioration in the quality of ore, shows how much progress has been made in the last 10 years at Appleby-Frodingham. It is natural to speculate on the fundamental causes of this improvement, since this may give a clue to the possibility of improvements elsewhere.

According to present ideas, the coke charged to the furnace must serve four purposes:

(1) To render the burden permeable

(2) To provide heat in the stack for the preparation of the burden

(3) To provide heat in the bosh and hearth for chemical work, and to melt the iron and slag

(4) To perform chemical reduction.

Minimum coke consumption, under any particular operating conditions, may thus be limited by the need to fulfill any one of these requirements.

The information given in this and previous papers from Appleby-Frodingham indicates that the change in composition of the ferruginous part of the burden from 33% sinter to 95% of a much stronger sinter has radically altered the quantity of coke needed for each of these four purposes.

In the first place, the quantity of coke required to ensure sufficient permeability of the burden has been reduced. The narrower size range and greater strength of the sinter is important in the whole of the stack. In the larger pieces of ore, the removal of moisture and the decomposition of hydroxides and carbonates must tend to cause disintegration, whereas the sinter remains comparatively unchanged until well down the furnace. Further down the stack the ore becomes soft and deforms under the weight of the overlying burden at a much lower temperature than the sinter. This deformation must lower still further the permeability.

Finally although more wind is now blown per unit area of hearth, it has not been necessary to increase proportionally the permeability of the stock column to the blast. The practice of regular and severe checking enables the burden to move when part of the supporting effect of the pressure difference up the furnace is removed: 25 lb/in$^2$ pressure difference acting over the area of a circle 25 ft dia. gives a force of nearly 800 tons. This practice would not be possible if the burden were semi-plastic over any length of the stack, as when a large proportion of ore is present.

The heat requirements of the furnace are also radically altered, as is well brought out in Table IV of the paper.

To a first approximation, one may say that the heat in the bosh and hearth is provided by the combustion of part, at least, of the coke and by the sensible heat in the blast. Heat in the stack is provided by the hot gases rising from the bosh and hearth. The temperature at which the gases leave the bosh and hearth is determined by the grade of iron required. Thus while making a given grade of iron, the only way to increase the heat available in the stack is to increase the proportion of coke in the charge and decrease the blast temperature in order to maintain the same hearth temperature.

With 97% sinter, two factors combine to reduce the heat requirements in the stack, as compared with 35% sinter:

(1) More moisture and combined water in the ore

(2) More carbonate in the burden.

However, since the slag volume remains the same, the quantity of heat required in the bosh and hearth will be about the same in both cases.

As shown in Table IV, it has been possible to raise the blast temperature and lower the coke rate, while at the same time the top gas temperature has increased. Actual figures for this would be interesting.

The coke required for the chemical reduction of iron oxides apparently is not a factor in determining the minimum coke rate under these conditions. It is clear from the first two lines of Table IV that the coke charged with 97% sinter is more fully used for chemical reduction than when 35% sinter is used, despite the lack of reducibility of the sinter. No doubt this is due partly to the decreased amount of coke required for combustion, partly to the removal of $CO_2$ from decomposing carbonates in the lower part of the stack, and partly to the much higher softening point of the sinter, which should render it much more permeable to gas at temperatures of the order of 1000° C. Figures for the $CO/CO_2$ ratio for the top gas in each case would be of great interest.

In conclusion, it is tempting to ask why the blast temperature has not been increased still further beyond 750° C. Is it simply because the stove capacity is not available?

The experiments with bosh tuyeres may point the way to the possibility of eliminating the inactive zone in the centre of large furnaces. If this zone could be eliminated, it should be possible to increase the production from these large furnaces still further.

## AUTHOR'S REPLY

Mr. **Elliot:** I must thank Mr. Mitchell for his obvious interest in the paper.

The slag volume was not included in Table I but Table II shows that it has risen in the last 10 years and is now 25–26 cwt/ton of iron.

Mr. Mitchell complains that Table IV of the heat balances is misleading because the total B.t.u's shown is not the total needed to produce 1 ton of pig iron. I think we are sometimes apt to forget that we even require B.t.u's to bring Swedish ore into the works or from some other plant. The inclusion in the table of B.t.u's required to dry ore and to sinter the fines would be equally misleading because it would lead to the belief that the iron was more expensive to produce, which it is not.

The extra B.t.u's required for sintering the two burdens (including gas for ignition and the coke breeze consumption) are 4·55 million and 10·22 million respectively. The total B.t.u's are therefore 19·48 million for the 35% sinter burden and 23·17 million for the 97% sinter burden. The 2·8 cwt of coke breeze per ton of sinter is burned to $CO_2$ at 14·550 B.t.u./lb carbon, whereas an equivalent amount of metallurgical coke burned in the furnace would only generate about half this quantity of heat.

The comparison in the cost per ton of iron is possibly the most important one to make and this shows a considerable reduction in raw-material cost, to which should be added the extra profit arising from an increase of 25% in the make.

With regard to Mr. Mitchell's suggestion about calcination, it must not be forgotten that to calcine the rough part of the 35% sinter burden we should have to use at least 3 million B.t.u's/ton of iron without eliminating any sulphur from the ore. Does Mr. Mitchell really think that his suggestion could bring about an increase of 25% in the make?

Mr. Towndrow considers that improvements are possible by examining the practice of screening and sintering both at once. Some of our efforts to obtain such improvements are mentioned in the paper, but I can assure Mr. Towndrow that only by sintering the whole burden has it been found possible to get the present results from our furnaces. With regard to the suggestion that with low coke rates the margin for improvement is less, it must be admitted that coke rates of the order of those obtained in rich-ore practice are difficult to improve, but Glasgow is a long way from Scunthorpe.

Dr. Chesters asks about theoretical limits to furnace size. There is nothing wrong with a furnace of over 30 ft dia. and designs are on the board for relining *Queen Victoria* furnace to 30 ft 6 in. or 31 ft. The figure of 30 ft is more a theoretical limit than an actual one. We can visualize a blast-furnace operating with a high top pressure of 40–45 lb/in$^2$. How much will be made

from it cannot be known; the tonnage of a blast-furnace is the only measure of its efficiency.

As for Dr. Chester's point about refractories, it is his job to find the materials which will make for higher operating speeds. There is no reason to suppose that slag and iron temperatures are higher at the present rates of production.

Mr. Evans wonders what would be the limiting factor on output and mentions throughput time. During the week when *Queen Victoria* furnace made the record which has been mentioned, the throughput time was only about 6 h; the iron quality was quite normal and no ill effects were noticed. Perhaps when *Queen Victoria* furnace makes 2000 tons/day and the throughput time is less than 5 h we shall have further information on this subject. Slag disposal will certainly be a problem at Appleby-Frodingham but it is a problem that will have to be solved. It is impossible to say what will be the final limit, because problems arising out of new practice seem ultimately to solve themselves.

At Appleby-Frodingham, we think that bosh tuyeres are worth a lot of iron, especially when smelting semi-prepared burdens. They provide a cleaner bosh and increase the active area of the furnace stack. They are cheap to install and easy to abandon if they do not come up to expectation.

Mr. Greenough's valuable written contribution of his views on the reasons for improvements in the Appleby-Frodingham results (with which I am in agreement) is much appreciated.

Although blast temperatures have been increased from below 500° to about 750° C, it is quite safe to say that the furnaces would accept higher temperatures. However, with the higher blast volumes the stove capacity would not admit of a higher blast temperature with some reserve for emergencies. The stoves were designed when smaller tonnages were anticipated.

The top gas temperatures for the two burdens in Table IV were 160° and 210° C.

The $CO/CO_2$ ratios in the two cases were 3·08 and 2·70 but they are not strictly comparable, as the former was influenced by $CO_2$ arising from the ore while in the latter the whole of the $CO_2$ arose from carbon in the coke.

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## EXPANSION AT LYSAGHT'S

Mr. **W. L. James** (John Lysaght's Scunthorpe Works Ltd.), in introducing the paper "The Expansion Scheme at John Lysaght's Scunthorpe Works Ltd." (*J. Iron. Steel Inst.*, 1955, vol. 181, Sept., pp. 17–25), showed a large number of slides to illustrate the progress of the reconstruction.

Mr. **Richard Mather** (Skinningrove Iron Co., Ltd.): Mr. James's paper shows us how he successfully solved the difficult problem of modernizing works which were adequate when they were built, but which had not kept pace with current requirements. When I made my first visit to these works over 20 years ago, I remember thinking that Normanby Park had capabilities; but little was done to exploit these capabilities until after the last war. The results are due to the efforts of a team of men who knew what they were going to do and how they were going to get over the difficulties. I especially admire their solution of the difficult problem of completely rebuilding an O.H. melting shop while keeping it in operation, so as to adapt it for bigger crane loads on the casting side, larger furnaces, etc.

This paper will be a valuable source of reference to works engineers for a long time to come, not so much because the same solution could be adopted in other works, but because of the confidence it will give to other engineers, in showing them that what seems almost an impossible problem of adapting an old works into a new one can be solved.

Mr. James is to be commended for making use of adequate models of the entirely new plant, which could be used by men who were unaccustomed to using it and enable them to become familiar with it. When the time for the conversion came, there was not much time for preliminary training, because of the ever-pressing demand for output, but the use of models must have been a considerable factor in helping the men to reach the maximum output from the new plant so quickly.

I congratulate Mr. James, Sir Charles Bruce-Gardner (who supplied the finance and general initiative in the matter), and all their colleagues upon a very successful piece of necessary work, which has put a plant that was inadequate into the forefront of similar plants in the U.K. today. It will bear comparison with anything anywhere for achieving this particular purpose.

Sir **Charles Goodeve**, F.R.S. (B.I.S.R.A.): What is the price of land around the Normanby Park Works? Judging by the way the new plant has been tucked into a space hardly bigger than the original, one might deduce that the price is very high. Will the other half-million tons capacity which will probably be required before long be able to be fitted in without radical alterations?

### AUTHOR'S REPLY

Mr. **James**: Let us assume that we are making about 500,000 tons a year—and are hoping to make 600,000 tons, because the present plant is by no means finished yet. It would be impossible to provide an equivalent tonnage today, at the price paid then. It would need more than double the money. I imagine that we have one of the cheapest prospects there is in the country in that respect. We went from under 7000 tons a week up to the target figure of 10,500 tons, which is now getting nearer 12,000 tons. Having spent our money with the idea of getting 10,500 tons, we find we are now getting an additional 1000 tons of ingots per week.

The works are now very circumscribed, and it would be impossible to extend on the present site, but there is room on the opposite side of the road to build another works, and there is a railway connection. The cost of erecting it would be very heavy indeed. Whilst big outputs are very necessary, I would suggest that in any expansion scheme they must be achieved as economically as possible, so that when the easy days have gone our industry will be able successfully to withstand the challenge of competition.

# STEELMAKING AT REDBOURN

Mr. **C. Thomas** (Richard Thomas and Baldwins Ltd.): The melting shop manager at Richard Thomas and Baldwins has one of the most difficult steelmaking problems in the world; he makes iron simply from local stone and Northampton stone, without preparation plants or sinter plants.

This iron has to be made into steel of a very high quality. We make ingot iron, and all the steel for auto body sheets is 0·06% C, 0·03% S, and 0·02% P, and has to be of very high quality.

Mr. **S. R. Isaac** (Richard Thomas and Baldwins Ltd.): in presenting his paper "Steelmaking at Redbourn", which appeared in the September, 1955, issue of the *Journal* (vol. 181, pp. 44–48) said: The original building of the shop is unique in having the furnaces and the casting pit under one span. By far the greatest feature is that when the shop was built there were 55-ton and 60-ton furnaces, yet the shop was equipped with two 160-ton teeming cranes and two 100-ton hot-metal cranes. I suggest that the late Mr. Frank Thomas, who put down the shop, was very far-sighted. He visualized what the furnaces of today would be like. The developments carried out have fitted in easily with the original plan. The crane power and the space were available; we have not had to enlarge a culvert or a chimney, but there is more room between the furnaces than in many more modern shops; there is in fact room for 200-ton furnaces.

Our furnaces have been developed at Redbourn, by various people, by trial and error. Ours is the only large shop whose furnaces are entirely fired by coke-oven gas, at the moment with about 24-in. W.G. pressure to all but two of the furnaces. Two have been adapted to 60-in. W.G. pressure, another two will be adapted within a fortnight, and within the next six weeks the whole shop will be working at that pressure. I do not think that 60 in. is anything like the ultimate pressure, but after that it becomes a question of compressors and whether you are going to make a sufficient gain.

Every furnace has a graphitized dolomite hearth. We had initial difficulties with the Crespi-type bottom but I would not hesitate, if I were building a new furnace, to put it in without any sub-hearth bricks. We had difficulty when the first furnace broke out, but my reply to questions about the advisability of this method was that we had 30 other break-outs in three years, with bricks in the bottom. It was discovered why the bottom failed. The hearth was not built to receive a bottom without bricks. It had a thickness of dolomite of about 6 ft at the ends and about 2 ft in the middle, and every time we tapped it tended to rise a little in the middle. It was because the contraction was pushing it up. I am convinced that if we shaped the bottom of the casting to receive 12 in. of dolomite evenly overall it would work without bricks, but that would mean a major alteration; however, the sub-hearth bricks are not disturbed when renewing the monolith.

We have tried most other types of bottom; dolomite rammed with tar or burnt in, Basifirm burnt in, and magnesite burnt in. Good initial results were obtained, but after about 18 months they began to cause trouble. There was never enough time to remove and rebrick before installing the new bottom (anything up to 10 days) so that the bottom needs to last 10 years. With the Crespi-type we can take out the bottom in about 20 h without disturbing the hearth brickwork; another bottom was installed in 18–20 h. By very careful scheduling the normal repair period was not exceeded.

The bottom is not used for more than two years. It is removed before it begins to give trouble. That is the great advantage of the Crespi-type bottom.

A fair amount of work was done on all-basic furnaces, but we do not use them at Redbourn. We have now standardized at complete basic ends and silica main roof. All-basic roofs are uneconomical; but our ends last 3–4 years, and some last as long as five years.

The only other change in refining practice is the use of oxygen on the open-hearth furnaces. All the details of the operation will be published in a paper very shortly. The charts show the speed at which one can work with oxygen. The Americans claim that it increases refractory wear, and they use oxygen sparingly, particularly during the early stages. We claim the reverse. It is obvious that by creating greater heat by blowing oxygen and burning the same amount of fuel you will burn the furnace down, but by reducing the amount of fuel there is no increased wear on the refractories.

There are difficulties with the desiliconization of molten pig iron with oxygen; with iron of about 0·8% silicon everything went well; with high-silicon iron we had immediate difficulties with the sulphur. Soda ash is applied to our metal and it is skimmed and desiliconized; the slag if crusted over is very difficult to skim. With the increased temperature a reversion of the sulphur occurs. I set out in the paper a table showing three ranges of silicon and the amount of oxygen consumed in each case.

There is the all-important question of cost. Treatment of a ton of iron with oxygen at 11*s.* 6*d.* per 1000 ft$^3$ costs 2*s.* 3*d.*; lances, 7*d.*; ladles 2·75 *d.*; limestone 2·75 *d.*; maintenance and wages 12·05 *d.*; totalling 4*s.* 4*d.*

Mr. **T. G. Grey-Davies** (Partridge Jones and John Paton Ltd.): I do not favour a furnace bottom with no bricks, and I do not think that this type of bottom has a great future. Perhaps Mr. Isaac will enlarge upon his paper and give some further reasons for his opinion. I find many complaints nearly always relate to the furnace bottom. Here Mr. Isaac has been wise. He changes furnace bottoms every two years. Mr. Isaac says that the graphitized hearth is still there after two years, but he does not trust it any longer. I agree with him.

Scrap quality is deteriorating from a charging standpoint; every steelmaker will agree that the time is long overdue for scrap merchants to get down to the job of producing scrap suitable for the ever-increasing melting rates of modern furnaces.

A number of South Wales plants use Scunthorpe iron, but we use quite a bit of imported iron—Russian iron with 2% Mn and a low percentage of phosphorus, and also sulphur: 50% Scunthorpe to 50% Russian iron is a good proportion.

Mr. Isaac has developed his desiliconization and desulphurizing process to meet local conditions. The quality of the pig iron is of paramount importance.

Furnaces in South Wales are changing over rapidly to oil and are making an increasing use of oxygen. At Ebbw Vale the whole plant is being changed over to oil. Mr. Isaac has shown wonderful courage in using a furnace with a very large single air uptake. I asked him what he considered to be the relative merits of a single air uptake furnace and a furnace of conventional design,

and he said he thought it did a better job and made refining easier. There may be more oxidation and you may get rid of some sulphur during the early stages.

Mr. Isaac says that " sulphur must be removed before blowing oxygen, unless the carbon is above 0·30%, when some oxygen may be used to reduce carbon to about this level." What is the phosphorus content at that stage? Does the sulphur not reduce until the phosphorus content is down?

Mr. **Isaac:** I was not arguing about the matter of brick bottoms so much from the point of view of safety, but merely to show that it could be done. It is obvious that bricks are a further safeguard. Bottom boils are caused by previously made holes containing metal which you cannot get out. I have yet to see all such metal dragged out. I think that you can blow it drier with oxygen. If you blow with oxygen it is no longer metal but oxide. With the graphitized bottom, after two years you begin to reach the stage when you no longer have enough bottom, and you begin to have bottom boils. Roughly 50% of the bottom is left at that stage.

The merits of a single air uptake as against a double uptake is a very difficult question. It must be for each individual plant to decide. The working speed is about the same in both. Sulphur trouble is less with a single air uptake, but the cost is a little higher.

Coke-oven gas firing and oil firing are completely different from using producer gas. Producer gas has a much lower sulphur content, plus the fact that it is passed through regenerators and desulphurized. The use of high-sulphur fuel, as well as the quality of the pig iron, can have very material influence on the amount of removable sulphur.

Anybody contemplating installing sloping ends should get out designs and do a little model work, to observe the flow patterns. There will then be a clear indication of the wear on the ends. He must also make sure that the gas is burnt before it starts going down the end.

It is widely acknowledged that the higher the carbon the easier it is to remove sulphur. The phosphorus at that stage is as low as 0·03% because unless you have a really good basic slag you cannot hope to remove your sulphur. With a good basic slag your phosphorus automatically goes. Phosphorus never troubles us, although we have 1·4–1·5% in our pig iron.

Our system of furnace pressure control was initially unsuccessful. At that time our dampers were controlled by means of a series of pulleys. Then the dampers were brought immediately next to the air valve in the valve arch; so the dampers are almost vertically underneath the damper control instrument, and dispensing with the system of pulleys we got perfect operation.

Mr. **R. Mather** (Skinningrove Iron Co. Ltd.): Many scrap merchants send poor scrap to the steelworks. Incoming scrap must be examined and rejected outright if unsuitable. I predict a general improvement in quality will ensue if this policy is pursued.

Dr. **D. Binnie** (Lancashire Steel Corporation Ltd.): Mr. Isaac has dealt with the soda-ash treatment of blast furnace iron and does not appear to have any problem on the subject of the removal of the soda slag from the ladle, a problem which has proved something of a deterrent against the general use of a process successful chemically.

All blast-furnace metal does not necessarily go into the mixer; some goes direct into the open-hearth which means that some soda slag will find its way on to the banks.

Has Mr. Isaac had any trouble from the soda slag or is it that the benefits attained more than outweigh the problems of effective skimming and from any cutting of the banks which might occur?

Could Mr. Isaac also say if he has developed any special means for the removal of the soda slag?

Mr. **Isaac:** As the first essential of good skimming is to get the metal over quickly to the shop after casting, we make two ladles to a cast. We put the soda ash in and get little trouble skimming the first ladle because the slag is still molten. The crane drivers soon get skilled at this operation and pour off 60%; the remainder is rabbled off. Skimming is however difficult when the cast becomes a little cool owing to slag crusting. We then put it into the mixer, without doing much damage or cutting the banks.

Dr. **P. H. Sykes** (British Oxygen Co. Ltd.): In Mr. Isaac's paper there is a cost comparison between finishing with oxygen and finishing with Swedish ore. In the oxygen table he does not seem to have accounted for the loss of the hot metal which he would have derived from the ore, which decreases the benefit from the use of oxygen. On the other hand, with the greater total output, the saving in depreciation and labour per ton of steel would introduce a factor of about twice as much as the loss of yield: it would give an even better overall figure than he has reported.

In another part of the paper he makes the interesting observation that a very low carbon content can be obtained with very much lower iron content in the slag by blowing oxygen. The compositions given in Tables I and II in the paper give a blow with ore and oxygen compared with a blow with oxygen alone. Using oxygen alone, a very low carbon was achieved but the iron in the slag is higher than with the ore and oxygen. These are only individual figures and I should be very interested to know the average iron content of the slag under those two different conditions.

Mr. **Isaac:** To reduce the carbon to 0·024%, working with ore or oxides only, we have to increase the iron in the slag up to 30%, but when using oxygen in place of some of the ore, we find we can get the carbon down to 0·024% with as little as 15% iron in the slag. In practice our average iron in the slag is 20·0% which is 10% lower than when not using oxygen.

We contend that this raising of 10% iron in the slag offsets the gain in iron which would result from the use of ore.

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## THE DEVELOPMENT OF LOW-GRADE ORES AT APPLEBY-FRODINGHAM

This discussion was based on the paper by Dr. L. Reeve, entitled the " Development of Chemical Methods for the Treatment of Low-Grade Ores at Appleby-Frodingham," which appeared in the September, 1955, issue of the *Journal* (vol. 181, pp. 26–40).

Mr. **D. A. Oliver,** C.B.E. (B.S.A. Group Research Centre): The Institution of Mining and Metallurgy recently debated the need for a national or Commonwealth minerals policy and a National Mineral Dressing and Process Metallurgy Laboratory, so that Great Britain and the Colonies might keep up with other nations operating on private enterprise.

Dr. Reeve's paper disproves the general rule that this country is behind others in modern extractive methods

as applied to minerals. It might be noted that the question of vanadium recovery obviously touches minerals policy.

In this research the chemistry has been worked out on a small laboratory scale and carried forward into the first pilot-plant stage with due regard to chemical engineering principles and the cost of production, with particular reference to the energy consumed. The unusual progress through the ferric-oxy-chloride stage to the pure $Fe_2O_3$ (referred to on pp. 32 and 33) is particularly elegant.

The possibility of recovering vanadium from indigenous ores is of great potential importance to Britain, as at present we largely rely on Belgium for supplies of $V_2O_5$ where it arises as a by-product in the refining of lead–zinc concentrates. Little is said in the paper of the possible economic value of vanadium recovery.

The paper also illustrates the serious gaps in our basic knowledge of this subject, for besides doing the work described, Dr. Reeve's team had to determine equilibrium data, work that might well have been carried out by university research. It is creditable that so much pure and applied chemistry has been undertaken during this research at Appleby-Frodingham.

The remark on p. 36, relative to the retarding effect of the products of reaction ($Fe_2Cl_6$) in conjunction with water vapour, reminded me of work with which I was associated in studying chromizing reactions on steel using chromous chloride in the vapour phase. In the case of chromium we also got the intermediate compound corresponding to ferric oxy-chloride. A deeper study of Dr. Reeve's paper may assist in resolving some of the difficulties in that field.

The remark that some of the processes described in the paper may prove economic is stimulating, and it would be interesting to hear from Dr. Reeve if he intends to industrialize the process in a still larger plant, or to follow some of the other alternatives he mentions, viz. to find sponge iron as an end product. If sponge iron were obtained as the end product either in a pure or in a carburized form, it could be taken straight to the steel furnace, instead of going through the pig-iron stage.

In dealing with an inexpensive material such as a low-grade ore, the economic aspects must be considered. The work of this paper leads to utilization of the low-grade resources of this country and suggests possible alternative courses.

Chlorine chemistry has been popular in recent years. The application by Dr. Gross of the chlorine recovery process for extracting aluminium out of mixed aircraft scrap was a great technological advance. The process is worked on lines parallel to those outlined by Dr. Reeve, and very pure aluminium chloride is distilled over, while a lot of undesirable impurities are left behind. This process has been licensed in Canada and the U.S.A.

Knoll's application in titanium extraction metallurgy, where titanium tetrachloride is the base chemical produced, is a further example. But the base price both of aluminium and titanium is many times greater than that of iron, which gives the process a better chance economically.

Mr. **E. W. Voice** (British Iron and Steel Research Association): In the past there have been many technical papers showing how difficult it is to persuade chamosite to yield its iron content by normal mineral dressing methods. But Dr. Reeve's paper gives details of a chemical method which yields all the ferric iron as essentially pure $Fe_2O_3$. The ore used was crushed to 30–60 mesh and the chloridizing reaction times quoted are 1–1½ h. Would there not be advantages in reducing those reaction times to minutes or even seconds by using more finely divided ore?

There was little reference in the paper to the physical state of the ferric oxide produced. Is it a very fine powder or is it granular, and if so what is the particle size of the pure ferric oxide produced? Mention is made of precipitating the oxide on to rich iron ore. What is the carrying capacity of this ore, or is it only used for starting purposes?

Nature seems to have helped Dr. Reeve in sorting out the sulphur, phosphorus, and vanadium but was extremely unkind in demanding that the water-vapour concentration should be kept so low if the chloridizing reaction is to proceed: 450,000 ft³ of HCl circulated for every ton of $Fe_2O_3$ is a very large quantity.

Excellent heat recuperation would be vitally important in the overall process if the heat requirements are to be kept on a level that is at all reasonable. Unfortunately, Dr. Reeve gives very little information about the heat requirements, so with this paper alone it is not possible to estimate what the cost of the process is likely to be.

Again, Dr. Reeve does not discuss the final uses of the commercially pure $Fe_2O_3$. If it is to be used in quantity to produce iron, the only practical process would appear to be to use the blast-furnace. It seems a waste to use an expensive process in purifying the iron oxide to such a degree, then to contaminate it with the necessary coke and fluxes in a blast-furnace. Consequently, Dr. Reeve's comments on the possibility of going straight to iron were very interesting.

Much has been said about the relative efficiency of the blast-furnace, but there is general agreement that it is efficient on iron usage and extremely inefficient on phosphorus removal. This must be borne in mind when considering Dr. Reeve's process.

At this meeting we have had two papers on the chemical treatment of low-grade iron ores at Appleby-Frodingham: Dr. Reeve's paper on producing a sulphur and phosphorus free iron oxide and Mr. Elliot's paper on producing saleable pig iron with some sulphur and some phosphorus. The relative merits of these two processes of chemical treatment can only be resolved by detailed data on the costs and market values of the products.

Mr. **R. J. M. Dixie** (Ore Mining Branch, United Steel Companies) wrote: Dr. Reeve's most interesting paper mentions briefly previous attempts to concentrate our lower-grade iron ores by purely physical means. The presence of chamosite in appreciable quantities in these ores renders a very high iron recovery impossible and the present attack on the problem by chemical methods is welcome.

The paper shows that considerable success has been attained in the laboratory to obtain a high iron recovery and the lines of development for a pilot scale plant indicated.

The results obtained by using Northampton Sands ironstone suggests that this ore is a most promising material for future experiments. H.M. Geological Survey Report "The Northampton Sands Ironstone, Stratigraphy, Structure and Reserves, 1951" suggests that considerable tonnages of low-grade high-silica iron ore can be obtained from this bed. These low-grade deposits occur on the fringes of the field, either as highly oxidized outcrops or under deep cover down dip of the areas at present being exploited. In the first case the deposits will be brown ores with little ferrous iron and a very low lime content, while in the latter case they will be green or grey ores with a high ferrous iron and an appreciable lime content. Dr. Reeve states that ferrous iron is lost in the tailings unless the ore is oxidized at 400–600° C before chloridizing, and also that an appreciable lime content is detrimental to iron recovery. The 'brown ores' would seem most suitable for treat-

ment although there may be a greater tonnage of low grade 'green or grey ores' that could be treated after an oxidizing roast.

This paper mentions briefly the pilot of full-scale plant operation, but as with the work on 'water washing' of Northants ores, there is no doubt that the cost of the preparation plant to render the ore 'as mined' suitable for this process would be very considerable and might more than outweigh the saving in freight in transporting concentrates rather than raw ore to the works.

Mr. **E. T. Sara** (United Steel Companies) wrote: The point was made in discussion that the material produced by this chemical process is very pure. This is a significant technical point, and it is a matter of economic importance also.

It should be noted that the process right down to the iron stage can be independent of carbon. There are places in the world where iron and steel industries may arise in the future where coal is not available. The presence of cheap electricity, oil, or natural gas could provide the necessary fuel and reducing agent. There are existing processes that could be applied more economically than traditional processes in locations of this kind, but they often produce iron of inferior quality, whereas the chemical process described in this paper produces material of very high quality.

Dr. **P. Herasymenko** (New York University) wrote: Dr. Reeve has to be congratulated on his very stimulating and bold approach to the problems of extraction of iron values from iron ores. While many practical difficulties remain to be solved, it appears possible that his method may in future replace the present pyro-metallurgical methods of iron and steel making. On the credit side of the chemical method will be the elimination of:

(i) Blast-furnace smelting with its requirements for good-grade ore and coke, and with its problems of slag disposal;
(ii) The open-hearth refining and of all slag-control headaches.

Iron oxide can be converted by low-temperature reduction to phosphorus- and sulphur-free iron powder or sponge, so that only melting furnaces will be required to produce steel, with considerable savings in the consumption of alloying elements.

One important aspect of the chlorination of iron oxide by HCl has not been mentioned by the author. The prevalent reaction at elevated temperatures is as follows:

$$Fe_2O_{3(s)} + 6\ HCl_{(g)} = Fe_2Cl_{6(g)} + 3\ H_2O_{(g)}$$

This reaction is accompanied by a decrease in the number of moles in the gas phase. Therefore, equilibria and rates of reaction will depend not only on the ratios of water vapour and hydrogen chloride, but also on the partial pressures of gaseous compounds. From recent literature data, it may be calculated that the free energy, $\Delta G°$, of the above reaction can be represented by the following linear equation:

$$\Delta G° = +2430 + 22{\cdot}04\ T$$

where $T$ is temperature in ° K. The equilibrium constant, $K_p$, is given by the formula:

$$\log K_p = \log p_{Fe_2Cl_6} + 3 \log p_{H_2O} - 6 \log p_{HCl} = \frac{-\Delta G°}{4{\cdot}575\ T}$$

The following table shows the equilibrium pressures of the dimer, $Fe_2Cl_2$, at 700° K (427° C) for two sets of partial pressures of water vapour and hydrogen chloride gas, the ratio $H_2O/HCl$ being kept constant:

| $p_{H_2O}$, atm | $p_{HCl}$, atm | $p_{Fe_2Cl_6}$, atm |
|---|---|---|
| 0·01 | 0·10 | $1{\cdot}86 \times 10^{-6}$ |
| 0·10 | 1·00 | $1{\cdot}86 \times 10^{-3}$ |

This example illustrates the effects of the partial pressures of water vapour and hydrogen chloride on the equilibrium content of ferric chloride (dimer) in the gas phase. The rates of chlorination will be influenced by partial pressures of water vapour and hydrogen chloride in a similar manner.

Table IV is said to represent "approximate $H_2O/HCl$/iron oxide equilibrium data." Actually, the data show roughly the rate of chlorination at various temperatures under almost stagnant atmospheres. The heats of exothermic reactions on p. 35 should have negative sign. The old European sign convention is now abandoned.

I believe these minor remarks will not detract attention from the importance of the pioneering work performed by Dr. Reeve.

## AUTHOR'S REPLY

Dr. **Reeve:** Mr. Oliver's remarks are much appreciated. The various points raised are rather in the way of passing comment, except the reference that the economics of low-grade ore was obviously a different proposition from the economics of a metal like aluminium or titanium. I agree, but was the argument the correct way of putting it? Mr. Oliver said that since the cost of low-grade ore was so small we had a difficult problem. In fact, the decisive point is what is the margin between the cost of low-grade ore and the price that a very pure high-grade ore will fetch. That is the margin to which we have to work.

Recent developments in chlorine metallurgy bear an obvious relationship to some of the processes described in the paper. But I pointed out that there are important differences between chlorine metallurgy and chloride metallurgy as described in the paper. We tried Cl, and for the reasons stated we would not recommend its further use for the treatment of these low-grade ores. Cl is too active; it removes not only Fe, but also some Si, Al, S, and P. There is also the cost of the carbon addition. Mr. Oliver's reference to the importance of vanadium recovery is noted. We are very conscious of the technical and economic importance of this part of our process, and further work on this aspect is now proceeding.

Mr. Voice raised a number of detailed points which can be quickly answered. First, on the possible advantages of a reduction in the size of the particles; he mentions 30–60 mesh. Actually we used everything below 16 down to 200 mesh. It is legitimate to enquire, why not reduce everything to below, say, 100 mesh and get an increase in reaction rate? There are two answers: the basic problem of economics is not strictly the reaction rate even though it takes 1–1½ h to complete the reaction. The average time which a particle remains in a fluidized bed will be controlled by the volume of ore in the bed. The effect of speeding up the reaction rate would require shallower beds and therefore lower blowing pressures, which would be an economic advantage. On the other hand, the velocity of gas-flow would have to be reduced with smaller particle size. The volume of gas blown would remain unchanged since this is fixed by equilibrium. The net effect would be an increased reaction-chamber diameter, which would add to the capital costs. Dust losses from the finer particles would also increase.

The physical state of the $Fe_2O_3$ mentioned by Mr. Voice is an extremely interesting point. When $Fe_2O_3$ is deposited from a gaseous mixture of $FeCl_3$ and water vapour, on to particles of $Fe_2O_3$ in a fluidized bed, it is

extremely tight and adherent. Visual examination suggests that it is crystalline; in some cases the crystals are large enough to be seen by the naked eye. The initial particles, tend to grow in size, though there is some counteracting tendency breaking them down. Quite large percentages, several times the weight of the bed, can be deposited without affecting the general fluidizing properties. In order to double the average particle diameter, a 700% addition by weight would be required. Ferric oxy-chloride when produced is softer and less adherent on the initial $Fe_2O_3$ particles in the bed, and dust losses tend to be higher. On subsequent hydrolysis of the ferric oxy-chloride the $Fe_2O_3$ is literally deposited " on itself."

The volume of gas used is large and its handling becomes an important problem as does heat recuperation. The condenser/evaporator system is also quite big and expensive, therefore the volume of gas required must be reduced. Further work is proceeding on a number of improvements in this section.

To feed the end product described (about 99% pure $Fe_2O_3$) into a blast-furnace seems a gross contamination of very pure material. Some work has been done on the production of sponge-iron from the end product, but we have not gone very far with this because of other work on hand.

Mr. Dixie's remarks are noted. Satisfactory recoveries have been obtained by chloridizing both types of Northampton Sands ores. Some of these are of such low Fe and high Si content that they could not be used economically in the blast-furnace in their present condition; some concentration would be essential if they are ever used.

Mr. Sara's comments relating to the possible production of high-grade sponge-iron from the final concentration product, using a gaseous reducing agent, are also of great interest. As already indicated in my reply to Mr. Voice, this possibility has not been forgotten.

Dr. Herasymenko, in his contribution, makes a similar suggestion. His further remarks concerning the possible improvement of the ferric chloride equilibrium pressure by raising the partial pressure of the remaining gases are of considerable interest, especially with the use of still higher pressure than in the examples which he quotes. Similar suggestions have been made to us from other sources.

Whether the economic advantages which might follow would compensate for the extra cost of these higher gas pressures and for the increased engineering complexities involved is a matter which needs more careful theoretical and experimental investigation. Other complications are the possible influence of increased pressure on oxy-chloride formation and on the stability of ferric-chloride hydrates.

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## ORGANIZATION FOR MAINTENANCE

This discussion was based on the paper by Mr. J. L. Gaskell, entitled " Organization for Maintenance " which appeared in the September, 1955 issue of the *Journal* (vol. 181, pp. 71–83).

Mr. **J. L. Gaskell** (Appleby-Frodingham Steel Company) presented the paper.

Mr. **H. M. Morgan** (South Durham Steel and Iron Co., Ltd.): The statement that increased mechanization will result in an increase in the ratio of mechanical to operating personnel is important, for it is often the engineering personnel who suffer the first reduction whenever costs increase.

Appleby-Frodingham employ a lot of outside contract labour; the machine shops operate virtually as a separate company, and the whole of the structural maintenance is carried out by their associated constructional company. Is this labour included in the ratio of 3 : 2, given by Mr. Gaskell ?

A works of the size and importance of Appleby-Frodingham must have a regular flow of trainees to cover their normal requirements and to replace skilled personnel who leave to go to firms with less effective and ambitious training schemes. Do the numbers of assistant plant engineers include some of these trainees or are they all fully qualified engineers ?

There is no mention of plant engineers having any day or shift boiler-shop labour. What happens when a plater, burner, or welder is required quickly ?

Are the ' first-aid ' workshops individually staffed with machinists, or how far have the lines of demarcation been overcome ?

No doubt Mr. Gaskell is justifiably proud of the results achieved by joint consultation, careful planning, and proper training of personnel, but does he think the same spirit exists today that existed before 1939 ? Have the target dates of the time and job schedules been achieved by employing more labour or paying additional incentive bonuses than was the practice before the war ?

The graphs of mechanical delays are interesting but there is only a small increase in output between 1946–47 and 1947–48, despite the working of five extra shifts. Taking the slabbing mill, with an ingot throughput of 409,000 tons on 12 shifts, I reckon it could give 580,000 when working 17 shifts—yet this figure was not attained until 1952–53.

Everyone will agree that the standard of maintenance and the appearance of the plant at Appleby-Frodingham is exceptionally high. At Cargo Fleet we cannot claim to compare with this; there is no separate inspection system except where this is necessary under the Factory Acts, and all routine maintenance is dependent upon the goodwill of foremen, charge-hands, and day fitters. My recollection is that in our 40-in. cogging mill, with a lower throughput, we averaged 1 h 57 min loss per week through mechanical delays for the last half year. I am not suggesting that Mr. Gaskell is doing anything wrong. He is fortunate in his staff and I am sure that he would not allow such a thorough and costly organization for maintenance to continue if the results to date had not justified it.

Mr. **J. L. Daniel** (Stewarts and Lloyds Ltd.): The growth of maintenance organization is bound up with increasing mechanization, but it may be that the peak number of men employed on maintenance is being approached. Mr. Gaskell does not agree, but how much further does he think we shall go, having in mind the vastly improved design of various units of heavy iron and steelworks equipment. One example of improvement is the modern blast-furnace top, which required practically no engineering maintenance between campaigns, other than repairs to the receiving hoppers and chutes.

The plain overhead crane can be designed to give long periods of trouble-free running. Two 50-ton hot-metal ladle cranes at Corby, built in 1943 and 1944, are totally enclosed and have all ball- and roller-bearings. A breakdown of any description on either of these cranes is rare. I look forward to the day when all overhead cranes are well designed and generously proportioned to enable them to deal with the heavy duties entailed in iron and steel manufacture. A time must also come when all rolling

mill equipment is robustly and expertly designed so that mid-week failures will be things of the past.

The ratio of operational to maintenance labour is said to be about 3 : 2. How is this ratio derived ? Does the total of personnel on works maintenance include central engineering shops, locomotive repairs, and wagon repairs ? Does it include bricklaying and general labouring, or is it solely in respect of maintenance fitters and electricians, and their assistants ?

The Corby labour ratio is lower than this, probably because of the output by Appleby of finished products, such as sections, compared with the semi-finished product of strip for tube-making produced at Corby. It is difficult to make comparisons unless complete analyses of both organizations are available.

Figures 2–4 would be of more general interest if similar charts or figures showing the down-time at the section mills had been given. Little or nothing has been mentioned of the methods of maintenance in the section mills. Most of us are aware of Appleby-Frodingham's products of rolled steel sections, and it would have been instructive to compare methods of maintenance with very much smaller organizations producing the same kind of material.

The central engineering shops of Appleby-Frodingham are mentioned as very important factors in the overall maintenance system. This revives the argument of whether main spare parts should be bought outside or manufactured within the company using them. At Corby, few spares are made in the engineering shops; what is known there as the central engineering shop only carries out work of immediate or near-immediate requirements, such as breakdowns and certain other items which can be carried out more conveniently on the site.

Without the capacity at Corby for making spares on a larger scale, it is necessary to carry considerably higher stocks. The organization and administration of the spares department are of great importance, and the department is under the charge of an experienced senior engineer with a staff of clerks and assistants who carry out the routine work of record-keeping and re-ordering. Official re-ordering of spares is carried out by the central buying department. It would be interesting to hear from Mr. Gaskell the extent to which spares are ordered from outside at Appleby-Frodingham.

In his concluding remarks, Mr. Gaskell referred to the omission of much which has a bearing on maintenance, such as the training of personnel. That is understandable with a paper of such magnitude, and I hope that at some time in the future an opportunity will be found to discuss the kind of training required to make a good maintenance man.

Mr. **J. H. Powell** (The Steel Company of Wales, Ltd.): As a production man, I should like to ask Mr. Gaskell if he considers that the central engineering shop really works. Does he get the repairs delivered at the right time, and when he gets them do they fit ? If he had his time over again would he not divorce on a very much bigger scale, the mills from the melting shop, and the melting shop from the blast-furnaces ?

I saw no signs of his mills being pushed for output. How much would his planned maintenance be affected if the mills had to work 20 shifts and really roll high tonnages ?

Mr. **R. A. Lake** (Richard Thomas and Baldwins): Most of the industry has very bad overhead cranes which require a lot of maintenance. The same objections apply to a good deal of gear in the melting shops and mills today. If there is insufficient finance for brand new plant would Mr. Gaskell recommend us to try to convert existing plant piecemeal, to a better design ?

Mr. **P. E. Peck** (British Thomson-Houston Co., Ltd.): The increasing use of automatic control demands corresponding maintenance facilities. A more important figure than the ratio of operating to maintenance personnel is that of total personnel to steel output. If this is decreasing then increased maintenance can be justified. Can Mr. Gaskell give any past and present figures which indicate the trend ?

## AUTHOR'S REPLY

Mr. **Gaskell**: In reply to Mr. Morgan, we do use contract labour in the present labour supply conditions, which in maintenance work is largely confined to platelaying. Contractors are also employed on new work. None of this labour is taken into account in arriving at the ratio of about 3 : 2, but the operating departments also use contract labour and their inclusion or exclusion makes no material difference to the ratio. All classifications of labour are included in arriving at the ratio.

The division is between operating or production workers, and maintenance workers: if those definitions are used there cannot be much argument whether a certain man is operative or maintenance. Staff personnel are not taken into account in deriving the ratio since difficulties immediately arise, e.g. how to classify wages department staff between operating and maintenance.

The designation ' assistant engineer ' is applied only to engineers fully qualified in the broadest sense, and does not include trainees.

With regard to burners and welders at Appleby Steelworks, there is one of each per shift. The need for platers on shift does not arise.

At the ' first aid ' shops at Appleby Steelworks there is a turner and a machinist on 6/2 and 2/10 shifts. During the night-shift, machine work is sent to the central workshops. All fitters or turners are trained fundamentally as fitter-turners.

It is said that the boys of today are not what they were in our young days, but this has been repeated for generations. The economic differences between 1939 and now must be remembered. Incentive bonuses are paid in certain cases such as in the slab shear operation mentioned in the paper. Target dates are achieved not by employing more labour but fundamentally by using labour more effectively through greater managerial skill.

I regret it was not made clear that the 12-shift working during 1946–7 did not apply to the whole year. It applied for a significant part of the year arising from the very severe weather conditions which occurred early in 1947, and the note on the graphs was originally intended to convey that 1946–7 was an abnormal year.

At Appleby Steelworks we have what must be regarded generally as an old plant. However, for the financial year just ended, a continued general improvement in engineering weekly average stoppage times was achieved as shown:

| | 1953–54 | 1954–55 | |
|---|---|---|---|
| Slabbing Mill | | | |
| Mech. | 2 h 43 min | 2 h 12 min | Gain 31 min |
| Elec. | 35 min | 40 min | Loss 5 min |
| 10-ft Mill | | | |
| Mech. | 3 h 30 min | 2 h 53 min | Gain 37 min |
| Elec. | 56 min | 45 min | Gain 11 min |
| 7-ft Mill | | | |
| Mech. | 1 h 35 min | 1 h 18 min | Gain 17 min |
| Elec. | 54 min | 54 min | Equal |

Concerning the level at which maintenance activities are carried on, the annual reviews over 10 years referred to on p. 83 of the paper show man hours and costs to be held at a satisfactory level, and they certainly do not suggest profligacy.

Mr. Daniel asked whether we were approaching the limit with maintenance manning. As mechanization increases, the ratio of maintenance people to operational people is almost bound to increase, even if there is no increase in the actual numbers of maintenance people, but I cannot foretell the limit.

The purpose of the Figs. 2–4 was to provide supporting evidence for the conclusions drawn from the specific example of the inspection system at Appleby Steelworks. There would appear to be scope for a paper devoted entirely to inspection methods and systems.

The average engineering delays per week at the Frodingham Mills for the financial year just ended are:

| | Mechanical | Electrical |
|---|---|---|
| 42-in. Cogging | 11 min | 10 min |
| 32-in. Mill | 36 min | 20 min |
| 15-in. Mill | 10 min | 8 min |

I cannot give a direct answer on the extent to which spares are bought out or made in the central workshops, for this is entirely a matter of economics, and alternative prices are frequently sought. If the balance is fine, the decision may turn on how heavily loaded the central shops are at the time. It must also be remembered that capital is invested in the shops and men employed, and in some circumstances it may be necessary to make locally at some slight apparent uneconomy.

I thank Mr. Daniel for his contribution on the spares organization adopted at his company, and strongly support his plea for an opportunity to discuss fully the very important subject of training suitable engineers for the industry.

In reply to Mr. Powell, the central engineering shops do work and parts do fit. There are occasional exceptions when something goes wrong, for in general the central shops can only work to the information supplied with an order. Development of the central shops was inevitable, for the number of local shops carrying out the machine shop work for the whole company, at some time had to be regarded as unsatisfactory and uneconomic. I hope this answers the question about divorcing blast-furnace, melting shop, and mill functions. Mr. Oram, manager of the central engineering workshops at Appleby-Frodingham, may like to add to these remarks.

If Mr. Powell gained the impression that our mills are not pushed for output, that may be something of a tribute to the standard of maintenance achieved. The Frodingham cogging mill, put down in 1948, is not working anywhere near its ultimate capacity. As quoted, delays in the slabbing and plate mills indicate considerable pressure on the equipment there. If the mills had to work 20 shifts, planned maintenance would need to be more intensively developed. Under such conditions, surely Mr. Powell would not envisage the down shift occurring simultaneously on all mills.

In reply to Mr. Lake, our overhead cranes are rebuilt or replaced if and as necessary, and as with melting shop and mill equipment the gears are enclosed. Piecemeal replacement or improvement is precisely what we are doing in the Appleby Mills rehabilitation work, and circulatory lubrication systems are applied wherever possible. The roller tables replaced in the 7-ft mill are now equipped with plain bearings and circulatory lubrication, and maintenance is extremely low.

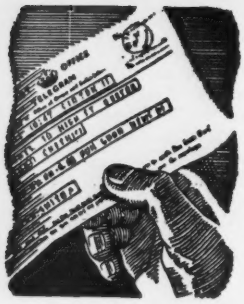
I agree with Mr. Peck that the relationship of total personnel to output matters in the long run, but as mine is essentially an engineering paper I wish to emphasize that engineers must expect the engineering cost component to come under increasingly close scrutiny.

Recent figures published by the British Iron and Steel Federation indicated a ratio for the whole of the industry of about 2 : 1. The figures at July 1955 were 160,014 on process work and 83,895 on general maintenance work associated with production. Additionally, 40,886 were employed on administration, technical, and clerical work. Extensive statistical data is available from the same source.

Mr. **C. G. Oram** (Appleby-Frodingham Steel Company): The central engineering workshops certainly do work. This is proved by the increase in turnover from about £500,000 in the first year, to something like £1,250,000 for the current year, with less personnel operating.

The central engineering workshops certainly make the 'things' fit. Site engineers should ask themselves exactly what they require, and not as is often the case, order a shaft 4 in. dia. with no limits shown on their requirement. Furthermore, precision measuring equipment is necessary. This we have, and can measure the article when we produce it. Some 400 orders are speedily dealt with every week: I doubt whether outside deliveries would equal this.

About 40% of the workshops personnel are now engaged on producing new plant for replacements, or developments, and in all this work we are to time.



# *N E W S*

## Announcements and News of Science and Industry

## IRON AND STEEL INSTITUTE

### Special Meeting in France

The programme of the Special Meeting of The Iron and Steel Institute, to be held in France from 5th to 14th June, 1956, is given in this issue of the *Journal*, pp. 15–17.

## NEWS OF MEMBERS

Mr. **D. C. Brown** has relinquished his post as Metallurgist with Rotol Ltd., Gloucester, and has taken up a position as Metallurgist with C. A. Parsons and Co., Ltd., Newcastle-on-Tyne.

Mr. **Y. A. Calderwood** has transferred to Belfast to take charge of the recently established factory of the Wellman Smith Owen Engineering Corporation Ltd.

Mr. **D. F. Campbell** has been appointed Deputy Chairman of the Indian Steelworks Construction Company.

Mr. **A. G. E. Carrier** has left the Mechanical Engineering Section of the Plant Engineering Division of B.I.S.R.A. to join Ewbank and Partners Ltd., London.

Mr. **W. Castledine** has been appointed Lecturer in Management Studies at the North Staffordshire Technical College, Stoke-on-Trent.

Mr. **D. K. Coutts** has been appointed Manager of the Bombay Technical Office of the Mond Nickel Co., Ltd.

Dr. **T. B. Crow** has left Foundry Services Ltd., and has taken up an appointment with E. A. Lewis and Co., Ltd., Birmingham.

Dr. **B. G. Davis** has left the Royal Naval Engineering College and has taken up a post with the Research Laboratories of the General Electric Co., Ltd., Wembley.

Mr. **L. S. Davis** has left the Chemistry Department of B.I.S.R.A. to join Welding Supplies Ltd., Gillingham.

Mr. **T. Dennison** has been appointed Head of the Technical and Development Department of the British Iron and Steel Federation.

Mr. **H. P. Forder,** at present Director and Deputy General Manager of Samuel Fox and Company Ltd., is to become Director and General Manager.

Dr. **F. A. Fox** has been appointed Chief Superintendent of the Defence Standards Laboratories, Department of Supply, Maribyrnong, Melbourne.

Mr. **J. G. Frith** has transferred from the Park Iron Works of Davy and United Engineering Co., Ltd., to the Associate Company, Duncan Stewart and Co., Ltd., Glasgow.

Mr. **W. B. H. Gallwey** has been appointed Chairman of British Acheson Electrodes Ltd., Sheffield.

Mr. **F. B. George** has been appointed General Manager of the Consett Iron Company, with a full seat on the Board.

Mr. **A. Hartley** has left the British Iron and Steel Research Association to take up an appointment as Metallurgist with John Rigby and Sons Ltd., Parkhouse Wire Mills, Bradford.

Mr. **S. R. Howes,** at present Director and General Manager of Samuel Fox and Company Ltd., is to retire on 30th June, 1956, but will remain on the Board of the Company.

Dr. **J. E. Hurst,** C.B.E., J.P., has been awarded the distinction of Doctor of Engineering *honoris causa* in the University of Karlsruhe.

Mr. **A. H. Ingen Housz** (*Honorary Vice-President*) has been appointed an Honorary Member of the Royal Netherlands Institute of Engineers.

Mr. **D. Jamieson** has taken up an appointment as Chief Metallurgist of Trenton Steelworks, Trenton Industries Ltd., and Eastern Car Company, Trenton, Nova Scotia.

Mr. **L. J. Jones** has left the Electrical Engineering Section of the Plant Engineering Division of B.I.S.R.A. to join D. Napier and Sons Ltd., Acton.

Mr. **B. S. Keeling,** formerly Secretary of the British Iron and Steel Federation, has been appointed Deputy Director (Economics). He will be responsible for Economics, Statistics, Intelligence, and Federation publications, in addition to his existing responsibilities for Development and for Labour, Training and Accident Prevention.

Mr. **W. McCabe** has been appointed Plant Metallurgist with Dominion Iron and Steel Ltd.

Mr. **A. J. Pluhar** has been appointed Manager of the Non-destructive Testing Division of the Warnock Hersey Co., Ltd., with headquarters in Toronto.

Dr. **F. D. Richardson** is the recipient of the Sir George Beilby Memorial Award for 1956 in recognition of his work on the thermodynamic properties of high-temperature systems, with special reference to iron smelting and steelmaking.

Professor **E. C. Rollason** is relinquishing the Henry Bell Wortley Chair in Metallurgy at the University of Liverpool to take the Chair of Industrial Metallurgy at Birmingham University in September, 1956.

Mr. **J. E. Srawley,** formerly Director of Research of the Arwood Precision Casting Corporation, has taken up an appointment as Supervising Metallurgist with the Metallurgy Division of the Naval Research Laboratory, Washington.

Dr. **F. Wormwell** is the recipient of the Sir George Beilby Memorial Award for 1956 in recognition of his work on surface reactions, with special reference to the mechanism of metallic corrosion, oxidation, and passivation processes.

Dr. **H. K. Worner** has taken up the position of Director of Research to the Broken Hill Proprietary Co., Ltd., Shortland, New South Wales, and associated Companies.

Mr. **A. Young** has taken up an appointment with Colvilles Ltd., Ravenscraig Works, Motherwell.

### Obituary

Mr. **William Trevor Bowen** (*elected* 1954), of Worcester, on 7th February, 1956.

Monsieur **Maurice Geib** (*elected* 1945), Manager of Union Sidérurgique du Nord de la France, on 23rd February, 1956, at the age of 64.

Mr. **John William Walker** (*member* 1950–54), a Director of Sanderson Brothers and Newbould Ltd., Sheffield, on 28th February, 1956.

## CONTRIBUTOR TO THE JOURNAL

**D. H. Houseman, M.A., Ph.D.**—W. J. Rees Research Fellow in Refractory Materials at the University of Sheffield Department of Metallurgy.

Dr. Houseman was born in 1925 and received his early education at Archbishop Holgate's School, York. From 1943 to 1947 he served in the Royal Air Force, gaining a Commission as Radar Navigator. He then entered Queens' College, Cambridge, and read for Part I of the Natural Sciences Tripos, graduating in 1949. In 1950 he read for Part II (Metallurgy) of the Natural Sciences Tripos and, in the same year, started research work on the interactions of molten metals and refractory materials, for which work he was awarded the Ph.D. degree.

In 1953 he joined K and L Steelfounders and Engineers Ltd., Letchworth, as Research Metallurgist, responsible for the supervision and execution of research and development projects associated with the production of carbon and alloy steel castings.

Dr. Houseman took up his present appointment in February, 1955, and is studying fundamental problems of interest to the refractories industry.

## EDUCATION

### Courses in Metallurgy in Yorkshire

The Yorkshire Council for Further Education has published "*A Guide to Courses in Metallurgical Subjects*," copies of which are available price 6*d*. post free from the Secretary, Y.C.F.E., Basinghall Buildings, 52 Basinghall Street, Leeds 1.

The following courses are presently available :

*Diploma, Final Degree, and Professional Courses*

*Note:* Full-time day courses may be offered where there are sufficient students.

B.Sc. (Eng.) (London External) Final Examination in Metallurgy

| | | |
|---|---|---|
| Bradford | D | E |
| Middlesbrough | *See* note above | |
| Rotherham | D | |

Licentiateship of the Institution of Metallurgists

| | | | | | |
|---|---|---|---|---|---|
| Bradford | D | E | Rotherham | D | E |
| Middlesbrough | D | E | Sheffield | D | E |

(In addition a 'sandwich' course is provided at Middlesbrough, i.e. full-time attendence at college for six months in each of three years, with the remaining time spent in industry.)

*National Certificate Courses*

O.N.C. Metallurgy

| | | | | | |
|---|---|---|---|---|---|
| Bradford | D | E | Rotherham | D | E |
| Huddersfield | D | E | Scunthorpe | D | |
| Leeds | D | | Sheffield | D | E |
| Middlesbrough | D | E | | | |

H.N.C. Metallurgy

| | | | | | |
|---|---|---|---|---|---|
| Bradford | | E | Scunthorpe | D | |
| Middlesbrough | D | E | Sheffield | D | E |
| Rotherham | D | E | | | |

*City and Guilds of London Institute Certificates*

Iron and Steel Operatives

| | | | | | |
|---|---|---|---|---|---|
| Middlesbrough | D | E | Scunthorpe | D | E |
| Rotherham | D | E | Sheffield (at district centres) | D | E |

Metallurgy (Intermediate)

| | | | | | |
|---|---|---|---|---|---|
| Bradford | D | E | Scunthorpe | D | E |
| Middlesbrough | D | E | Sheffield | D | E |
| Rotherham | D | E | | | |

Metallurgy (Advanced)

| | | | | | |
|---|---|---|---|---|---|
| Bradford | D | E | Scunthorpe | D | E |
| Middlesbrough | D | E | Sheffield | D | E |
| Rotherham | D | E | | | |

Foundry Practice (Intermediate)

| | | | | | |
|---|---|---|---|---|---|
| Bradford | | E | Middlesbrough | D | E |
| Doncaster | | E | Rotherham | D | |
| Halifax | D | E | Scunthorpe | D | E |
| Huddersfield | D | E | Sheffield | D | E |
| Keighley | | E | | | |

Foundry Practice (Final)

| | | | | | |
|---|---|---|---|---|---|
| Bradford | | E | Keighley | | E |
| Doncaster | | E | Middlesbrough | D | E |
| Halifax | | E | Rotherham | D | |
| Huddersfield | D | E | Sheffield | D | E |

Metal Finishing ; Metal Finishing Operatives ; Non-ferrous Metals Operatives

Courses will be arranged at any centre where there is sufficient demand.

D This denotes the provision of a part-time day, or part-time day and evening course, i.e. one designed for apprentices and other employees who may be released to attend college during normal working hours (usually one day per week plus evening attendance where necessary).

E This denotes the provision of an evening course, normally requiring attendance on three evenings a week.

List of Technical Colleges

Technical College, Great Horton Road, Bradford 7.
Technical College, St. George Gate, Doncaster.
Technical College, Hopwood Lane, Halifax.
Technical College, Queen Street South, Huddersfield.
Technical College, Lord Street, Keighley.
College of Technology, Cookridge Street, Leeds 2.
Constantine Technical College, Borough Road, Middlesbrough.
Technical College, Howard Street, Rotherham.
North Lindsey Technical College, Kingsway, Scunthorpe.
College of Commerce and Technology, Department of Science, Lancastrian Annexe, Bowling Green Street, Sheffield 3.

## NEWS OF SCIENCE AND INDUSTRY

### International Foundry Congress—Düsseldorf

The Verein Deutscher Giessereifachleute is organizing the 23rd International Foundry Congress, which is to be held in Düsseldorf from 1st to 9th September, 1956. Full particulars and forms of application may be obtained from the Secretary, Dipl.-Ing. Ph. Schneider, Verein Deutscher Giessereifachleute, Sohnstrasse 70, Düsseldorf, Germany.

### Australian Institute of Metals Conference—Newcastle

The 9th Annual Meeting and Conference of the Australian Institute of Metals will be held in Newcastle, N.S.W., from 21st to 25th May, 1956. The Annual Lecture will be delivered by Mr. R. Knight, General Superintendent of Steel Production of Broken Hill Pty. Co., Ltd., and Australian Iron and Steel Ltd., on the subject "*Recent Innovations in Steelmaking.*" At the two technical sessions a series of papers is to be presented forming a symposium on "*Surface Defects in Steel.*"

## University College Appeal for Engineering Department

An appeal for £2,000,000 to build and equip new and enlarged premises for the Engineering Department of University College, London, was launched at a meeting at the College on Wednesday, 15th February.

Addressing a distinguished body of representatives of the engineering industries, Lord Strang, Chairman of the Engineering Appeal Committee, made the point that young engineers trained at University College benefit by their contact with men who are following other careers. "I would conclude with an expression of personal opinion", said Lord Strang, "on a matter which seems to me to be of importance . . .I think engineers gain a great deal from receiving their education in an institution like University College which gives instruction in the humanities, laws, fine arts, architecture, town planning, and many other studies. Some of these studies are worked regularly into the training of engineers . . . But apart from this interlocking of their courses of study, our engineering students here mingle at large with the students of other subjects ; they are not confined to a technological world, but can become full and complete men."

Viscount Chandos spoke in support of the appeal, emphasizing the present need for more engineering graduates in industry and in teaching. In a joint appeal to industrial firms, Lord Cohen, Chairman of the College Committee, and Lord Strang point out that graduate engineers are qualifying at a rate that falls short of the national demand. Owing to inadequate accommodation and facilities, the College can accept only one of every nine applicants ; of these nine, at least seven are fully qualified and suitable for entry to the Engineering Department. Because of war damage the Engineering Departments have since 1945 been no more than restored to their pre-1939 condition and are still housed in quarters which have hardly been extended for 30 years.

The College's present annual output is about 70 graduate engineers. As soon as the sum of £300,000 is raised, the first stage of the building programme can be completed, and this output will be stepped up by 50%. If the £2,000,000 Appeal is met in full, the College will be able to accommodate about 600 engineering students, corresponding to an annual intake of about 200, including candidates for higher degrees.

**Artist's impression of the final appearance of the University College Engineering Department**

Under its development plans, the College has acquired new sites adjoining the present Gower Street buildings. One site is immediately available for construction work estimated to cost £300,000, which is the first target of the Appeal. As further funds become available two additional buildings, including a tower block of 12 storeys, will be added.

Since 1945 University College has had an uphill task in carrying on its work, after suffering very heavy war damage. Well over £1,500,000 has been spent on post-war reconstruction of the College, but part only is recoverable from war-damage claims. The balance has been met by sums from the University Grants Committee and other sources.

The initial response to this Appeal for funds for new engineering buildings has been most encouraging. Contributions amounting to a quarter of a million pounds have already been received, chiefly from the larger industrial groups. But a massive sum remains to be raised.

The Engineering Departments, which date from the foundation of the College, 120 years ago, are among the oldest established in Britain. University College itself can claim to be the original 'University of London.'

## Fulmer Research Institute

Sir Ben Lockspeiser, K.C.B., F.R.S., who recently retired as Secretary of the Department of Scientific and Industrial Research, has joined the board of the Fulmer Research Institute, Stokes Poges.

## Translations of Soviet Periodicals

Complete English translations of 46 Soviet periodicals in the fields of chemistry, physics, biology and medicine, agronomy, geology, electronics, and associated theoretical and applied sciences will be published by Consultants Bureau, 259 West 14th Street, New York 11, N.Y., U.S.A. Translations will begin with the issues for July, 1956.

## Expansion of Gartsherrie Ironworks

Extensive alterations and additions to the Gartsherrie Ironworks of Bairds and Scottish Steel Ltd., at Coatbridge are expected to double production. Output is to be increased from 150,000 tons to 350,000 tons of pig iron a year and all grades will be machine-cast in future. Early work to be undertaken at the Gartsherrie plant will be the construction of a new blast-furnace, the first of two for which provision has been made. New ore-stocking, screening, and sintering plants are also being installed, and the battery of coke-ovens is being doubled.

## Conditions in Iron Foundries

The Joint Standing Committee for Conditions in Iron Foundries has published its first Report on the work accomplished since 1947. It gives a summary of the conclusions reached in the first comprehensive investigation into the pulmonary risks of iron and steel foundry workers and outlines the activities of employers, trade unions, and the Government. Between October, 1946, and December, 1953, about £3,000,000 was spent by the industry on amenities and improvements in working conditions. Sections of the Report are devoted to the determination and suppression of dust; dust control by water is discussed and there is a description of a new wet de-coring bar developed by the British Cast Iron Research Association. Reference is made to spark arrestors on cupolas and risks of carbon monoxide poisoning at the cupola as well as during mould drying and ladle drying.

The Report of the Committee is published by H.M.S.O., price 4*s*. 6*d*.

### Conference on Properties of Materials at High Rates of Strain—London

The Council of the Institution of Mechanical Engineers, in collaboration with its Applied Mechanics Group Committee, is taking steps to organize a Conference on the Properties of Materials at High Rates of Strain, to take place in London in March, 1957. The materials under consideration will include only those used in the manufacture of mechanical engineering structures or elements, and will exclude fluids. The meeting will probably last from two to three days.

### Conference on Lubrication and Wear—London

The Institution of Mechanical Engineers is arranging to hold a Conference on Lubrication and Wear from 1st to 3rd October, 1957.

### Electron Microscopy

The Association des Ingénieurs Sortis de l'École de Liège has arranged to hold a Conference on the Industrial Applications of Electron Microscopy in May, 1956.

### Record Output of Iron Castings

Distington Engineering Co., Ltd., Workington, Cumberland, achieved a record production of 1663 tons of iron castings during the week ending 28th January, 1956. This surpassed the previous best output of 1560 tons, for the week ending 14th January, 1956.

### Record Outputs from Appleby-Frodingham

During the week ending 11th February, 1956, one of the 300-ton O.H. steel melting furnaces at the Appleby-Frodingham Steel Company, Scunthorpe, produced a record 3022 tons of ingots. The previous best from this furnace—the "O" furnace in the company's Appleby melting shop—was 2913 ingot tons in the week ending 3rd October, 1953. "*Queen Anne*" blast-furnace, one of Appleby-Frodingham's four "*Iron Queens*," also set up a new record recently by producing 8260 tons of iron, 40 tons more than in her former record week ending 28th January, 1956.

### Trophy for Industrial Safety

Sir George Earle, Chairman of the Associated Portland Cement Manufacturers Ltd., has presented a trophy to the Royal Society for the Prevention of Accidents, to be awarded annually for an outstanding contribution to industrial accident prevention. The trophy will be presented each year at the Society's National Industrial Safety Conference. This year the Conference will be held at Scarborough from 11th to 13th May, 1956.

### New Appleby-Frodingham Plant

Further coke-oven and by-product plant is to be constructed at the Appleby-Frodingham Steel Co., Ltd., Scunthorpe, by the Woodall-Duckham Construction Ltd. The contract includes two batteries each of 33 W-D Koppers Coke Ovens, with a daily carbonizing capacity of 1330 tons, duplicate oven machines, additions to the existing coal-handling plant to supply the new ovens' bunker, a new coke wharf and quenching station and additions to the existing coke-handling plant, a new primary by-product plant with extensions to the existing by-product and benzole plants.

### Britain's Largest Arc Furnace

Birlec Ltd., of Birmingham, are to construct a second arc melting furnace at the Stocksbridge works of Samuel Fox and Co., Ltd. It is to be larger than the existing 60-ton furnace, which is the biggest of its type in the U.K.

### Steelmakers' Blue Glasses

At the request of B.I.S.R.A., Chance Brothers have developed a new glass for the inspection of furnaces. It is a compromise between the traditional cobalt glass, with its high temperature-discrimination properties, and a green glass, with a poor temperature discrimination but good protective properties.

### Fifth World Power Conference—Vienna

The Fifth World Power Conference will be held in Vienna from 17th to 23rd June, 1956. Membership of the Conference is open to all persons possessing appropriate professional qualifications or occupying responsible posts in the British fuel and power and related industries (including 'user' industries). A number of post-Conference technical tours, lasting 8 to 14 days, have been arranged, extending from Austria into the frontier regions of Germany, Italy, and Yugoslavia.

Twenty-seven papers are being submitted by the British National Committee in a total of about 300 papers to be presented at the Conference. Full particulars, and a copy of the General Programme, may be had from the Secretary, British National Committee, World Power Conference, 201 Grand Buildings, Trafalgar Square, London, W.C.2.

### Industrial Uses of Oil Fuel

Shell-Mex and B.P. Ltd. announce that Mr. H. Cunliffe has been appointed General Manager (Industrial Fuels) in accordance with their policy of devoting specialized attention to the industrial uses of oil fuel. Mr. Cunliffe has had a long career with the Company and during the war served at the War Office in the Directorate of Supplies and Transportation, being concerned with petroleum supplies.

### Heavy Steel Casting for Lackenby

A very complicated heavy steel casting has recently been delivered by the English Steel Castings Corporation Ltd. to the Darnell Works of the Davy and United Engineering Co., Ltd., Sheffield. The casting was a 142-ton 'C' frame of about 26 ft length, 12 ft width, and 8 ft depth. It is intended for the 1350-ton shear which is being built for Dorman Long as part of a contract for a new blooming and slabbing mill plant at the Lackenby Rolling Mill.

### New Blast-Furnace at Margam

On 10th January, 1956, Mr. H. Peake, Chairman of the Steel Company of Wales Ltd., performed the lighting-up ceremony which brought into operation the new No. 4 blast-furnace at Margam Works. This furnace has a hearth diameter of 29 ft 9 in.—the largest in Europe—and its ironmaking capacity exceeds 10,000 tons per week. It has its own stockyard, capable of handling 150,000 tons of ore.

A new feature for Margam Works is the scale car track, which runs at ground level and thus facilitates cleaning and repair. Air for the furnace is provided by a 125,000 $ft^3$/min axial-flow turbo blower of Swiss construction, the first steam-driven axial-flow turbo blower to be used in the U.K. Ninety new coke ovens, which are needed to provide the extra coke required by No. 4 blast-furnace, have also been brought into operation.

### Chemical Apparatus and Equipment Congress—Frankfurt

The twelfth Chemical Apparatus and Equipment Congress and Exhibition will be held in Frankfurt am Main from 31st May to 8th June, 1958. It is being organized by the Deutsche Gesellschaft für chemisches Apparatewesen.

### British Oxygen Gases Ltd.—Sales Technical Service Department

On 20th February, 1956, Sir Frederick Handley Page, C.B.E., officially opened the new Sales Technical Service Department of British Oxygen Gases Ltd., at Cricklewood, London, N.W.2. The "S.T.S." Department, established in 1935, provides information concerning the equipment and techniques used in welding, cutting, and flame-heating processes, and the new building contains a comprehensive range of demonstration machines, a process development shop concerned with the application and development of all B.O.G. processes and customer liaison for specialized uses, and a welding school. Of particular interest is the hot top heating of ingots by means of a heavy-duty blowpipe, designed to eliminate cavitation and porosity.

### Changes of Name

The DAVID BROWN CORPORATION LTD. has formed a new subsidiary, DAVID BROWN INDUSTRIES LTD., to consolidate the manufacturing activities hitherto carried on by: David Brown and Sons (Huddersfield) Ltd., the David Brown Foundries Co., the David Brown Tool Co., the Keighley Gear Co., the Coventry Gear Co., David Brown-Jackson Ltd., David Brown Gears (London) Ltd., David Brown Machine Tools Ltd., and David Brown Tractors (Engineering) Ltd.

The SHELTON IRON, STEEL AND COAL CO., LTD., has been renamed SHELTON IRON AND STEEL LTD.

### Industrial Publications Received

▶ Illustrated brochure showing various metal articles before and after treatment by Lacromatic process of barrel-finishing—Lacrinoid Products Ltd.

▶ A 28-page history of rectifiers with over fifty illustrations and diagrams—Publication R.190—Hackbridge and Hewittic Electric Co. Ltd.

▶ Illustrated booklets by Hilger and Watts Ltd. on Spectrophotometer H 800, incorporating the Double Beam in Time System, Publication CH 310/3; Vacuum Grating Spectrographs, Publication CH 123/2; the Photoelectric Colorimeter for surfaces and transparent materials, Publication CH 389/2; Photoconductive Cells (British Patent 685288), Publication CH 357/3.

▶ Illustrated booklet on various types of John Thompson Water Tube Waste Heat Boilers.

▶ Portfolio containing booklets and full-colour photographs on peaceful uses of atomic energy with particular emphasis on the U.N. Geneva Conference, August, 1955—issued by the Union Carbide and Carbon Corporation.

▶ Catalogue of apparatus for general laboratory work and specialized techniques—Shandon Scientific Co., Ltd.

▶ Illustrated technical bulletin on low heat-storage insulating refractories—The Morgan Refractories Ltd.

▶ Illustrated booklet "More Blast Furnaces," the second edition of a quinquennial publication detailing blast-furnaces erected during the past 25 years—Ashmore, Benson, Pease and Co.

▶ Illustrated brochure on continuous "Gibbons-Thermo" furnaces—Gibbons Brothers Ltd.

▶ Illustrated technical leaflet on spheroidal graphite iron castings—Armstrong Whitworth (Metal Industries) Ltd.

▶ Illustrated technical leaflet on geared motors and speed reducers—Electropower Gears Ltd.

▶ Illustrated booklet on a new system of atmosphere control for direct-fired forge and reheating furnaces—The Incandescent Heat Co., Ltd.

▶ Illustrated leaflet on method of protecting structural steelwork against corrosion—Denso Products.

▶ Illustrated leaflet on acetylene generator—Linde Air Products Co.

▶ Three illustrated brochures on mains-frequency induction melting equipment, for cast irons, copper alloys, and light alloys—G.W.B. Furnaces Ltd.

▶ Leaflet on continuous galvanizing plant—The Incandescent Heat Co. Ltd.

▶ Illustrated news letter on non-destructive testing—Solus-Schall Ltd.

▶ Illustrated booklet on the heating of nickel—The Mond Nickel Co., Ltd.

▶ Leaflets on tropicalized Avo Meters and new signal generator—The Automatic Coil Winder and Electrical Equipment Co., Ltd.

▶ Booklet on methods of production and properties—"*Wiggin Nickel Alloys by Powder Metallurgy*"—Henry Wiggin and Co.

▶ Booklets on foundry floors and underground flues in refractory concrete—Lafarge Aluminous Cement Co., Ltd.

## DIARY

**4th May**—INSTITUTE OF PHYSICS (Non-destructive Testing Group)—Symposium on "*Principles of Penetrant Methods*"—47 Belgrave Square, London, S.W.1, 6.30 P.M.

**8th May**—NEWPORT AND DISTRICT METALLURGICAL SOCIETY—Works visit to the British Thomson-Houston Co., Ltd., Rugby.

**9th–10th May**—NATIONAL ASSOCIATION OF CORROSION ENGINEERS (North East Region)—Meeting on "*Control of Corrosion in the Chemical Industry*"—University of Buffalo, New York.

**9th–19th May**—Mechanical Handling Exhibition and Convention—Earls Court, London.

**12th May**—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—Annual General Meeting, followed by Presentation of Prizewinners' Papers—Central Library, Swansea, 6.30 P.M.

**12th–15th May**—VEREIN DEUTSCHER INGENIEURE—Centenary Celebrations, Berlin.

**15th May**—THE IRON AND STEEL INSTITUTE—Bessemer Centenary Lecture, by Mr. James Mitchell, C.B.E.—The Royal Institution, Albemarle Street, W.1, 6.30 for 6.45 P.M.

**16th–17th May**—THE IRON AND STEEL INSTITUTE—87th Annual General Meeting—The Royal Institution, Albemarle Street, W.1, 9.45 A.M. (16th May); Offices of the Institute, 4, Grosvenor Gardens, S.W.1, 2.30 P.M. (16th May), 9.45 A.M. and 2.15 P.M. (17th May).

**16th May**—THE IRON AND STEEL INSTITUTE—Ninth Hatfield Memorial Lecture on "*The Fracture of Metals*," by Professor N. F. Mott, F.R.S.—The Royal Institution, Albemarle Street, W.1, 11.45 A.M.

**16th May**—THE IRON AND STEEL INSTITUTE—Annual Dinner—Grosvenor House, Park Lane, London, W.1, 7.0 for 7.30 P.M.

**21st May**—AUSTRALIAN INSTITUTE OF METALS—Ninth Annual Meeting and Conference—Newcastle, N.S.W.

**22nd–25th May**—SOCIÉTÉ DE CHIMIE PHYSIQUE—Sixth Annual Meeting—Paris.

**4th–7th June**—METALS DIVISION, SPECIAL LIBRARIES ASSOCIATION—Conference—Hotel William Penn, Pittsburgh, Pa.

**5th–6th June**—BRITISH IRON AND STEEL RESEARCH ASSOCIATION (Metallurgy (General) Division)—Conference on Heat-treatment Practice—Ashorne Hill, Leamington Spa.

# *ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES*

## Iron and Steel Manufacture and Related Subjects

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## MINERAL RESOURCES

**The Mineral Industry of Quebec Province.** J.-P. Drolet. (*Ann. Mines*, 1955, **144**, Oct., 21–39). A comprehensive account of mineral deposits and workings in Quebec province is presented. The recent exploitation and development of iron-ore deposits in Northern Quebec is described in some detail.—B. G. B.

**Iron Ore Deposits in Southern Germany.** F. Beckenbauer. (*Z. Erz. u. Met.*, 1955, **8**, Mar., 93–101; May, 214–223). An outline is given of the geographical and geological distribution of iron ores in Southern Germany. They are Jurassic and Cretaceous sedimentary ores with 20–35% Fe. Some are concentrated magnetically after roasting to 40–45% Fe. Methods of mining, preparation, and beneficiation are described in brief.—E. C.

**Venezuela Iron Ore.** (*Bol. Min. Indust.*, 1955, **34**, Mar., 147–149). [In Spanish]. The Orinoco mines produced nearly 2 million tons of ore in 1953 and over 2 million in 1954. The installations are being improved in order to mine 10 million tons per annum. The ore, which is shipped to the U.S.A., contains 60–66% Fe, 1–4% $SiO_2$, 0·02–0·03% S.—J. R. P.

## ORES—MINING AND TREATMENT

**An Investigation of the Reactions Between Pyrrhotite and Sulphur Dioxide.** J. Aarvik and H. Aas. (*Tidsskr. Kjemi, Bergvesen Met.*, 1955, **15**, (1), 3–5). [In Norwegian]. The equilibrium of the reaction

$$3FeS_{1+n} + 2SO_2 = Fe_3O_4 + \frac{5+3n}{2}S_2$$

was determined at 700–1000° C by passing $SO_2$ through a column of synthetic pyrrhotite. The reaction between natural pyrites and $SO_2$ was also studied, unstable sulphur first being removed in nitrogen atmosphere. The influence on the reaction of calcium in the sulphide ore was studied in detail. The results obtained agree well with those of Morawietz and Rosenqvist.—G. G. K.

**Differential Thermal Analysis and X-ray Examination of Fe and Mn Bog Ores.** P. Ljunggren. (*Geol. Föreningens Förh.*, 1955, **77**, Mar.-Apr., 135–147). [In English]. The employment of D.T.A. revealed an endothermic reaction in Fe ores much lower than that of lepidocrocite and goethite, whilst Mn ores were shown to consist of hydrated compounds. X-ray analysis revealed the presence of $\delta MnO_2$ and manganous manganite in one sample.—G. G. K.

**Marmora's Iron Goes to Market.** C. Mamen. (*Canad. Min. J.*, 1955, **76**, Aug., 43–49). Details of stripping the limestone overburden, drilling and blasting, loading and haulage, hoisting, crushing and screening, grinding and concentrating, agglomeration, and storage and transportation at the Marmora Mine, Ontario, are given. A flow sheet is shown. Magnetic separation is followed by pelletizing in a vertical shaft furnace. The iron content of 37% in the ore is raised to 63–64% in the finished product. 500,000 tons of hematite pellets will be produced annually.—T. E. D.

**Pre-Production Safety at Marmora Mine.** D. F. Coleman. (*Queensland Gov. Min. J.*, 1954, **55**, Nov., 901–903).

**Ore Preparation and Handling at the West Hartlepool Works of South Durham Steel & Iron Company, Limited.** S. H. Walker. (*Iron Coal Trades Rev.*, 1955, **170**, June 3, 1261–1272). The author describes the planning and carrying out of a large-scale development scheme to increase production at the West Hartlepool works of South Durham Steel & Iron Co., Ltd. Particular attention is given to the installation of the new ore-preparation and handling sections and to the solution of typical problems involved.—G. F.

**Effect of Sinter Mix Composition and Additives on the Quality of Blast Furnace Sinter.** E. C. Rudolphy, C. W. Boquist, and D. J. Carney. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Nov., Sect. 1, 1179–1189). By sintering experimental samples on a production machine, the authors have studied the effect of variations in feed composition on the strength, bulk density, reducibility, chemical composition, and microstructure of the sinter. Increasing amounts of roll scale, ore fines, return fines, and blast-furnace slag were most beneficial to feed permeability, sinter bulk density, and strength, whereas burnt lime additions improved only the feed permeability. All the additions adversely affected the reducibility. The interrelationship of these properties is also considered.—G. F.

**Defects in Sinter-Plant Design.** A. I. Nikitin. (*Stal'*, 1955, (3), 204–208). [In Russian]. Sintering practice at two sinter plants in the U.S.S.R. is described in some detail to exemplify defects in design and operation. These and general points of sintering practice are discussed, and suggestions for improvements are made.—S. K.

**Reducibility Test of Iron Ore Lumps.** T. Ikeno and T. Hagiwara. (*Tetsu to Hagane*, 1955, **41**, Aug., 847–853). [In

Japanese]. Ores were crushed to various sizes (max. 3 in.) and reduced at 900° C in $H_2$, the rate being 20 l./min/kg; reduction was measured by loss in weight. Reduction velocities increased in the order magnetite < hematite < limonite, and with ore porosity. Curves between ore size and time for 90% reduction showed a trend to diverge between magnetite and dense hematite, and to converge with porous hematite and limonite. On the basis of 2-in. lump hematite of 24% porosity (as a suitable furnace size), the sizes of other lumps requiring the same time for 90% reduction are: magnetite 25–30 min, dense hematite c. 40 min, and porous hematite c. 50 min.—K. E. J.

**Aerofall Mill Finds Increasing Application.** R. A. Beals. (*Min. Eng.*, 1955, **7**, Sept., 842–845). The mill has a drum of high diameter/length ratio, and combines dry crushing and grinding of ore upon ore with classification by controlled air circulation. With Fe ore, the stages of secondary and tertiary crushing, screening, and rod-milling in the production of concentrates are replaced by the single unit. Details of various installations are given, including a 17-ft 3000-ton/day mill which reduces Fe ore from a primary crusher to −10 mesh size, at mill and air h.p. consumptions of 500 each.

**The Stripa Sink-Float Process.** J. Svensson. (*Z. Erz. u. Met.*, 1955, **8**, Apr., 147–152). [In German]. A detailed description is given of the new heavy-media process developed at the Stripa Mine, Sweden. The process utilizes a shaking trough with a moving heavy media bed of high solids content, permitting a high separating density (up to 3·3). The medium is a table concentrate of mixed magnetite and hematite. Very successful applications are described, including treatment of an iron ore (size range $2\frac{1}{2}$–$\frac{3}{8}$ in.) at a rate of 40 tons/h. Fe content of the concentrate was 48% with 11% in the tailings. Larger plants are under construction.—E. C.

**Oxidation of Pyrite.** A. Bergholm. (*Jernkontorets Ann.*, 1955, **139**, (8), 531–549). [In Swedish]. The results are presented of a study of the reactions between oxygen and pyrite in water or aqueous solutions which also aimed at analysing the mechanism of spontaneous ignition; 17 experiments were carried out on wet oxidation of pyrite, using special apparatus which permitted continuous measurement of oxygen consumption, at temperatures below 100° C. Dry oxidation at a limited rate was studied at 100–550° C together with combustion at a high rate above 550° C. Hints are given on the prevention of spontaneous ignition in sulphide minerals.—G. G. K.

**An Investigation of the Thermal Decomposition of Manganese Sulphate.** V. V. Pechkovskii. (*Zhur. Prik. Khim.*, 1955, **28**, (3), 237–244). [In Russian]. The mechanism and kinetics of the thermal decomposition of manganese sulphate were investigated as this reaction is important in the process of chemical beneficiation of manganese ores. On the basis of the results obtained optimum temperatures and carbon contents for the reaction are recommended.—V. G.

## FUEL—PREPARATION, PROPERTIES, AND USES

**Heat Balance Studies in an Integrated Steel Plant.** L. I. Dickinson. (*Iron Steel Eng.*, 1955, **32**, Oct., 120–125). This paper discusses the heat balance for a complete integrated plant (the Lackawanna works of Bethlehem Steel) and shows how with careful control it was possible to reduce the amount of purchased fuel from 0·184 net tons of bituminous coal equivalent per net ton of ingots to 0·106 net tons per ton of ingot steel.—M. D. J. B.

**Fluid Flow, Heat Transfer and Unit Operations.** T. K. Ross. (*Soc. Chem. Ind., Reports on Progress of Appl. Chem.*, 1954, **39**, 889–903). A special double-walled stainless-steel tube was used for the measurement of heat-transfer characteristics of molten metals. Work has been done on fine size reduction of coal and coke and on size separation by hydraulic settling. Other subjects reviewed are mixing and agitation, humidification and drying, distillation, adsorption, absorption and extraction, and crystallization, filtration, and centrifuging.

**Improvements in Firing Coke-Oven Gas and Liquid Fuels.** J. A. Leys. (*J. West Scotland Iron Steel Inst.*, 1953–54, **61**, 198–207). The author emphasizes the significance of momentum flux and shows how it and the flame length can be calculated. Examples are then given to demonstrate how the desirable supply pressure for coke-oven gas can be ascertained from these data. The author concludes with a description of a new type of liquid fuels burner for which operating results are given.—L. E. W.

**Flame Characteristics and Melting Rates.** E. J. Burton. (*J. West Scotland Iron Steel Inst.*, 1953–54, **61**, 208–216). The author briefly contrasts steelworks practice and current research and shows how the use of a B.I.S.R.A. burner should give an opportunity of elucidating the relationship between melting rates and steam : oil ratio for oil firing and gas pressure for coke-oven gas firing. A pyrometer for measuring gas temperatures is described and tentative conclusions for maximum furnace productivity are drawn.—L. E. W.

**Thermal-Radiation Tables and Applications.** R. V. Dunkle. (*Trans. Amer. Soc. Mech. Eng.*, 1954, **76**, 549–552).

**Furnace Fuels and their Application.** J. L. Adamson. (*Iron Coal Trades Rev.*, 1955, **171**, Aug. 12, 389–392). The author discusses the use of gaseous and liquid fuels in steel-melting furnaces and in heating furnaces for both ferrous and non-ferrous materials. The chief properties of different fuels are listed, and gas ports and burners are briefly considered. The various factors determining the choice of fuel for a particular furnace are discussed.—G. F.

## TEMPERATURE MEASUREMENT AND CONTROL

**High Temperature Thermocouple.** R. C. Jewell, E. G. Knowles, and T. Land. (*Metal Ind.*, 1955, **87**, Sept. 9, 217–221). A description is given of the development of the 20% Rd/Pt–40% Rd/Pt thermocouple, which will operate satisfactorily up to 1880° C. The couple is durable and stable, its e.m.f. being 3·19 mV at 1500° C and 4·525 at 1800° C. Some details are given of the methods used to calibrate the original couples, and data from users on the service life and performance of the new wire are presented.—P. M. C.

**The Selection and Application of Saturable Reactors.** D. E. Musgrave. (*Indust. Heating*, 1955, **22**, May, 926–936, 1088–1092). The characteristics of saturable reactors used in temperature-control devices are discussed. The devices have the advantage that they prevent furnaces from overheating under certain conditions.—A. D. H.

**Henry Le Chatelier.** E. N. Simons. (*Brit. Steelmaker*, 1955, **21**, Sept., 282–284). Le Chatelier's contributions to metallurgical science are reviewed, with particular attention to his work on pyrometry.—G. F.

## REFRACTORY MATERIALS

**The Magnesia Refractory Industry.** Reisch. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (11), 2205–2214). The history of the magnesia refractory industry is surveyed, and the importance of raw-material composition is mentioned. The use of magnesia in various basic refractories is outlined, and the use of these refractories in the steel industry is discussed.—T. E. D.

**The Ternary Systems Leucite–Corundum–Spinel and Leucite–Forsterite–Spinel.** J. F. Schairer. (*J. Amer. Ceram. Soc.*, 1955, **38**, May, 153–158). An investigation of the systems is reported. The data indicate the effects of impurities or additions to some combinations of refractory materials; the information is useful in considering some refractories and slags.—D. L. C. P.

**Phase Equilibrium Studies of Steel Plant Refractories Systems.** E. F. Osborn. (Amer. Iron Steel Inst.: *Indust. Heating*, 1954, **21**, Dec., 2515–2520; 1955, **22**, Feb., 375–380; May, 1039–1048, 1108–1110; June, 1258–1266; July, 1459–1466). Methods of studying phase equilibria in ceramic systems are reviewed. A general account of equilibria in quaternary systems based on $SiO_2$, FeO, $Fe_2O_3$, $Cr_2O_3$, and $Al_2O_3$ is given.—A. D. H.

**Modernisation of a Refractory Specialty Company.** R. S. Hall. (*Amer. Ceram. Soc. Bull.*, 1955, **34**, Aug., 248–251). The reorganization of a firebrick company producing Bessemer tuyeres, special shapes, and re-pressed products is described. Productivity was increased 83% per man.—D. L. C. P.

**First Czechoslovak Super-duty Silica.** O. Janák. (*Hutnické Listy*, 1955, **10**, (7), 396–400). [In Czech]. The theoretical and technological aspects of production as well as works experience, primarily in zebra-roof practice, are described.

**Some Applications of Organic Compounds in the Ceramic Industries.** W. L. German. (*Trans. Brit. Ceram. Soc.*, 1955, **54**, July, 399–409). Important applications of organic com-

pounds in ceramic materials and processes are reviewed with particular reference to modern experience.—D. L. C. P.

**An Apparatus for the Determination of the Moduli of Rupture and Elasticity in Brassbending to 1500° C.** S. D. Mark, jun. (*Amer. Ceram. Soc. Bull.*, 1955, **34**, July, 203–206). The apparatus was developed for testing small special-refractory specimens. The method of working is described, and a summary of the data on silicon carbide is reported.

**Factors Influencing the Physical Properties of Refractory Concretes.** W. C. Hansen and A. F. Livovich. (*Amer. Ceram. Soc. Bull.*, 1955, **34**, Sept., 298–304). The following are among conclusions illustrated by an investigation into concretes of calcium aluminate cement and crushed firebrick: (1) the hot and cold strengths independently depend on the firing temperature; (2) there is an optimum curing temperature; (3) strength is adversely affected by application of high temperature without curing; (4) stronger and denser concretes are obtained with the coarser aggregate and with the mixes of increasing cement contents; (5) deterioration in strength depends on time and temperature.—D. L. C. P.

**International Committee for the Improvement of the Life of Converter Bottoms and Linings.** (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (11), 2037–2108). The purpose of the committee is outlined and the following papers are presented. **Considerations on Dolomite Used in Thomas Steelworks.** W. Bading. (2039–2062). Raw-material specifications and methods of preparation are given in detail. Grinding and mixing of prepared material and methods of ramming bottoms are described. Types of ramming apparatus are illustrated. Designs of furnaces for firing bottoms and the effect of firing rates on performance are included. **Characterisation of Dolomitic Ramming Material. The Role of Phenols, Naphthalene, and Insoluble Matter.** J. Massinon. (2063–2069). The influence of tar constitution on the crushing strength of dolomite refractories is tested, and the results are reported in detail. A rapid increase in strength was found between 10–12% tar, with a maximum between 14% and 17%. **Making Converter Bottoms with Magnesia Tuyeres, in Particular by Vibration.** A. Latour. (2071–2080). The effect of rate of repairing bottoms on productivity is discussed. Details are given of the design of converter bottoms using magnesia tuyeres, and the steps in the fabrication are illustrated. Performance data are reported for a 15-month period. **Converter Bottoms with Tuyeres at the Thomas Steelworks of Hayange.** M. Remy. (2081–2089). Converter bottoms of unusual design are described and illustrated, and performance is outlined. **Problems in the Firing of Converter Bottoms.** H. Wübbenhorst. (2091–2106). An investigation of the problem is outlined, including factors affecting the life of converter linings. Details of various types of firing furnace are given with illustrations, and thermal performance is mentioned. **Sensitivity of Converter Bottoms to Cooling.** P. Delong. (2107–2108). The results of an investigation into the effect of intervals between charges on the life of converter bottoms are briefly reported.—T. E. D.

**Effect of Intermittent Operations on Refractories.** A. K. Blough and D. M. Schrader. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 84–86). The authors outline the effects of weekend shutdowns on roof life and bottom delays on 15-, 35-, and 50-ton electric furnaces.—G. F.

**Construction and Maintenance of Roofs on Large Top-charged Electric Furnaces.** K. L. Grant. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 74–81). Roof construction and maintenance procedure on a 20-ft dia. 80-ton electric furnace are described. The selection of suitable refractories is discussed, and results of trials of various bricks in different parts of the roof are given.—G. F.

**Refractory Bricks for Thomas Steelworks.** Lellig. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (11), 2215–2220). Tables are given of various types of brick, listing uses, performance requirements, cold structure, and chemical and physical characteristics. Suitable refractories for mixers, converters, ladles, nozzles, stoppers, and cupolas are included.

**The Firing of Converter Bottoms.** H. Wübbenhorst. (*Stahl u. Eisen*, **75**, Oct. 6, 1310–1317). The early stages of an international enquiry into the firing of converter bottoms are described. Attention is called to the varying designs of furnaces and the heating cycles employed in different works. Modern investigations on charging ratios, heating curves, gas consumption, and the influence of tar are discussed.—J. P.

**Steel Mill Refractories and Masonry.** (*Indust. Heating*, 1955, **22**, Mar., 599–608; Apr., 819–828; Aug., 1663–1666). Eleven papers presented at the 37th Conference of the National Open Hearth Committee of the A.I.M.M.E. are summarized. Subjects dealt with are hot-roof repairs, the strength of basic bricks at high temperatures, control of testing refractories, improvements in checker cleaning methods, and the design of checkers.—A. D. H.

**Refractory Mixes and their Application, No. 3: "Percromit–Plastic" for Hearths.** H. Zahlbruckner. (*Radex-Rundschau*, 1955, July, 518–522). [In German]. "Percromit–Plastic" is a ramming mix supplied ready for use in drums or plastic bags, obviating time losses in preparation. Detailed illustrated instructions are given for the complete operation of lining hearth floors with this material.—E. C.

## BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

**Erection and Operation of Blast Furnaces in Chile.** T. W. Plante. (*Iron Steel Eng.*, 1955, **32**, Aug., 143–149). Details are given of the new Chilean blast-furnace plant, and of the country's raw-material resources and potential industrial capabilities.—M. D. J. B.

**The Present State of Development of the Demag–Humboldt Low-Shaft Furnace Process.** H. Reinfeld. (*Radex Rundschau*, 1955, May/June, 431–439). [In German]. The economic and technical background for the low-shaft furnace are outlined. A detailed account is given of process, equipment, and operating experiences with a pilot-scale furnace of 12 tons/h capacity. Materials balances and product appraisals are provided to show the advantages of the process in dealing with non-coking fuels and with difficult ores such as fine-grained concentrates and ores of low grade.—E. C.

**Development in the Construction and Use of Blast-furnaces in the United States and in France.** P. Thierry. (*Mét. Constr. Mécan.*, 1955, **87**, Mar., 167–171; Apr., 269–273; May, 353–359; June, 471–477). Factors influencing the geographical location of blast-furnace plants are discussed. Differences in the layout of various plants are reviewed. Reference is made to the Fairless works in the U.S.A., which was built in 1951 and unlike many French works is not congested. Methods for handling the raw materials, molten iron, and slag are considered. The grouping around the blast-furnace of ancillary equipment (stockyard, stoves, gas cleaning plant, slag and metal lines) is reviewed and a number of layouts are given. Changes in the lines of U.S. and French blast-furnaces since 1930 are considered. The construction of blast-furnace hearths and stacks in the U.S.A. and in France is reviewed.—B. G. B.

**Blast Furnace Development.** R. A. Hacking. (*Proc. Staff. Iron Steel Inst.*, 1946–53, **61**, 117–138). An account is given of the development of modern blast-furnace practice. Brief mention is also made of high top pressure and the low-shaft furnace.—B. G. B.

**Evolution and Technical Progress in the Conception and Construction of Blast-Furnace Stoves.** Shoendoerffer. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (9), 1753–1771). The general design and construction of stoves is examined, and also the checker systems employed in the various parts. Some experimental and calculated heat-exchange data are given.—T. E. D.

**Ironmaking Trials in an Electric Smelting Furnace with Portuguese Raw Materials.** L. de Castro e Solla and L. Guimaraes dos Santos. (*Inst. Hierro Acero, Special Number*, 1955, **8**, July, 286–296). [In Spanish]. Sintering and iron-making tests in an experimental 500-kW single-electrode smelting furnace are described. Concentrates from the Vila Cora magnetite deposits (66% Fe, 5·5% $SiO_2$, 0·13% P, 0·16% S), screened and washed San Pedro de Cora anthracite (65·61% F.C., 5·91% V.M., 24·64% ash, 0·97% S, 0·09% P, 4500–700 kcal C.P.), limestone and dolomite from San Pedro de Sarracenos, and native charcoal were used. It was established that excellent sinters can be obtained in a total process time of ½ h, when the charge contains not more than 22% returned fines and the fuel, totalling only 5% of the total charge, consists of anthracite and charcoal in a 50 : 50 ratio. Optimum iron production is obtained when the fuel contains at least 75% anthracite, thus giving a power consumption of 2100 kWh and 15 kg electrode per ton and less than 200 kg of slag per ton.—P. S.

**High Shaft or Low-shaft Blast-furnace.** (*Prat. Soud.*, 1955, **9**, June-July, 102–106). [In French]. The essential require-

ments for good blast-furnace operation are briefly reviewed and the prospects of the low-shaft furnace are discussed. Reference is made to the programme of research, at present undertaken, which may decide the future of the low-shaft furnace.—M. D. J. B.

**Typical Blast-Furnace Practice on the North-East Coast.** D. Rist. (*Iron Coal Trades Rev.*, 1955, **171**, July 8, 79–84; July 15, 135–141). The author traces the history of blast-furnace practice on the N.E. Coast and describes the development of furnace lines to the modern design. He then discusses typical charging, burdening, and furnace performance in the area. Quality control is next considered, with special reference to type and quantity of coke used. The importance of maintaining a good taphole is stressed. Other items dealt with are tuyere design and alignment, water-cooling, and stove practice.—G. F.

**Gary Blast-Furnace Operates Successfully on 100% Sinter Burden.** R. W. Sundquist. (*J. Met.*, 1955, **7**, June, 737–741). The Gary Works of United States Steel Corp. has completed a successful test run with 100% sinter burden in No. 12 blast-furnace. The sinter used is described and operating data and statistics are given. The information derived from the test run is summarized, and the benefits of the sinter burden are discussed.—G. F.

**The Coke-Rate in Blast Furnaces.** J. Šárek. (*Hutnické Listy*, 1955, **10**, (10), 577–579). [In Czech]. The amount of slag formed is considered as a function of the composition of the charge. A diagram is constructed from which the specific coke consumption can be obtained as the sum of the specific consumptions necessary to melt 1 ton of pig iron and the corresponding amount of slag. The use of such a diagram in blast-furnace practice is discussed.—P. F.

**The Metallurgy of the Blast-furnace.** (*Arch. Eisenhüttenwesen*, 1955, **26**, Mar., 179–181). A report on a discussion of a paper by T. Kootz, A. Michel, and H. Rellermeyer (*Ibid.*, 1954, **25**, 299).—T. G.

**The Production of Iron in the Present and Future.** R. Durrer. (*Roll'schen Eisenwerke Werkz.*, 1955, **26**, Nov., 131–136).

## TREATMENT AND USE OF SLAGS

**Manganese from Steel Plant Slags by a Lime-Clinkering and Carbonate-Leaching Process.** Part I. Laboratory Development. R. A. Heindl, J. A. Ruppert, M. L. Skow, and J. E. Conley. (*U.S. Bur. Mines Rep. Invest.*, 5124, 1955, Apr.). The technique developed involves firing the slag to 2400° F in an oxidizing atmosphere, reduction at 1300° F of the resulting clinker in $H_2$, CO, or hydrocarbons, leaching the reduced clinker with ammonium carbonate solution and distilling off 50% of the ammonia when 90% of the manganese is precipitated as carbonate together with 15–30% of the iron. The manganese carbonate is subsequently calcined in an oxidizing atmosphere at over 2000° F to give $Mn_3O_4$ suitable for use in a ferromanganese blast-furnace.—B. G. B.

**Utilisation of High-Magnesia Slags in Cement Production.** M. J. Cleret de Langavent. (*Silicates Indust.*, 1955, **20**, Dec., 468–469) [In French]. It is shown that recent work discounts earlier views that a magnesium oxide contents above about 10% rendered slags inapplicable for cement production. A revision of older Standard Specifications in some countries is urged in view of the evidence now available concerning magnesia contents.—P. F.

**Foamed Slag.** A. Heczko. (*Silicates Indust.*, 1955, **20**, Nov., 419–423). Desirable properties of slags used for foaming are discussed with reference to steelmaking in the principal centres in the U.S.A. which supply most of the high-grade slag. Methods of manufacturing foamed slags, and their relations to the principal uses of the product are surveyed.

**A Comparative Study of Some Properties of Slags and Cinders.** A. Nicol and M. Domine-Berges. (*Silicates Indust.*, 1955, **20**, Nov., 410–418). The effects of pressure, temperature, solvents, etc., on three types of blast-furnace slags, a fused cinder slag, and fly ash obtained from Cottrell precipitators are compared. Experiments included dilatometry and chemical analysis. In order that a slag should 'take,' i.e. be useful for cement making, a certain minimum amount of lime must be part of its constituents.—P. F.

## PRODUCTION OF STEEL

**Aubert and Duval. Les Ancizes Works.** (*Aciers Fins Spec. Franç.*, 1955, Nov., 84–86). The Ancizes Works is mainly devoted to the production of alloy and special steels, the output exceeding 5000 tons/month. The works consists of electric-arc and H.F. furnaces for steelmaking, rolling mills, forging plant, and foundries.—E. A. C.

**Mexico's Most Modern and Largest Steel Plant.** G. Bennett. (*Blast Furn. Steel Plant*, 1955, **43**, Nov., 1267–1272, 1281). The stages in the development and present state of this integrated steelworks are described. The plant consists of two blast-furnaces, 4 O.H. furnaces, a universal hot mill, and a cold mill. Steel in sheet and plate form is the final product.

**Steel Manufacture.** W. Mathesius. (*Metal Progress*, 1955, **68**, Sept., 77–81). A brief review of the acid Bessemer, basic O.H., and electric furnace methods of steelmaking is made together with notes on the possible future adoption of continuous casting and improved basic Bessemer techniques.

**Presidential Address.** S. Thomson. (*West Scotland Iron Steel Inst.*, Paper No. 483, Oct. 21, 1955). The author surveys in broad outline the developments and tendencies during the past 50 years in the steel industry. The production data for the U.K. over this period are tabulated and analysed, and are used to suggest the future trends in steelmaking and rolling and to recommend the directions in which expansion should occur.—L. E. W.

**Appleby-Frodingham Steel Company (Branch of The United Steel Companies Limited): A Technical Survey.** (*Iron Coal Trades Rev., Special Issue*, 1955, Sept.). The survey consists of the following articles:

**The First Seventy Years.** L. G. Cooper. (5–8, 17).

**The Growth of Appleby-Frodingham Since 1934.** G. W. Wells. (14–16).

**Plant Design.** I. M. Kemp and H. Gissel. (18–30, 380).

**Coal Carbonizing Plant and Operations.** W. M. Hyslop. (31–38, 170).

**Mechanical Engineering on the Coking Plant.** A. Bridge and A. G. Mackay. (39–42, 47).

**Coke Ovens—Electrical Engineering.** D. R. M. Nisbet. (43–47).

**Working of the Ironstone in the Frodingham and Northampton Sands Beds.** C. B. Bailey. (48–54).

**Underground Mining: Dragonby and Santon Mines.** J. E. England and C. Smith. (55–60, 380).

**The Ironworks—Ore Preparation Plant and Operation.** N. D. Macdonald. (61–75).

**Ore Preparation—Mechanical Engineering.** A. Bridge and G. E. Mart. (76–86).

**Ore Preparation Plant—Electrical Engineering.** D. R. M. Nisbet. (87–100).

**The Ironworks—Plant and Operations.** H. S. Ayres, C. Dawson, and T. E. Mitchell. (101–111).

**Mechanical Engineering in the Ironworks.** A. Bridge and W. G. Crooke. (112–122).

**Electrical Engineering in the Ironworks.** D. R. M. Nisbet. (123–133).

**Organization of Iron Traffic Control and Pig Casting.** K. Morley. (134–139, 309).

**Steelworks Organization.** T. P. Lloyd. (140–144, 269).

**Steel Making: I. Plant and Operations; II. Furnace Fuels and the Use of Oxygen; III. Steel Furnace Maintenance; IV. Auxiliary Plant.** W. Jackson, R. Wogin, R. W. Marshall, and R. Johnson. (145–202, 317).

**Mechanical Engineering in the Frodingham Melting Shop.** P. Dixon and H. Clark. (203–206).

**The Plate Mills and Their Operations.** J. Dodd. (207–211, 222).

**Maintenance at the Appleby Steelworks.** P. Dixon and J. Watts. (212–222).

**Electrical Engineering in the Slabbing and Plate Mills.** R. L. English. (223–231).

**The Section Mills and Their Operations.** J. McLauchlan. (232–239, 252).

**Section Mills—Roll Design.** E. L. Burgess. (240–252).

**Mechanical Engineering in the Section Mills.** P. Dixon and E. S. Greenhill. (253–256, 262).

**Electrical Engineering in the Frodingham Mills.** R. Murison. (257–262).

**The Pit Arch Plant.** G. Fox. (263–266).

**The Engineering Services—General Principles and Organization.** J. L. Gaskell. (267–269).

**Central Engineering Workshops.** G. C. Oram. (270–281, 292).

**Civil Engineering.** R. B. Atkin. (282–292).

**Electrical Engineering: Power Supply and Distribution.** E. Clegg. (293–300).

**Lubrication.** H. Jones. (301–309).

**Plant Inspection and Maintenance.** P. Dixon and R. Hornsby. (310–315, 266).

**The United Steel Structural Company.** K. Paterson. (316–317).

**Engineering Research Department.** N. H. Turner, T. S. Burns, R. A. Kipling, R. C. Walthew, G. W. Cook, and E. Whitehead. (318–326).

**Works Railway Traffic.** E. R. S. Watkin. (327–330).

**Rail Transport.** W. E. Fowler. (331–332).

**The Road Transport Department.** H. F. Bowskill. (333–335).

**Company Research.** L. Reeve, G. Moore, T. S. Harrison, and A. Howard. (336–347, 350).

**Labour Management.** F. C. Davis. (348–350).

**Personnel Policy: History, Development and Existing Organization.** W. Geary. (351–369).

**Education and Training.** W. T. Wilson, M. J. Upton, A. Goodall, E. F. Brown, T. F. Alexander, and M. H. A. Dod. (370–374, 378).

**Medical Services and First Aid.** F. A. Shackleton and A. B. Hudson. (375–376).

**Works Civil Defence and Fire Service.** A. B. Hudson. (377–378).

**Some Chemical Engineering Problems of the Iron and Steel Industry.** A. H. Leckie. (*Chem. Process Eng.*, 1955, **36**, June, 211–214; Aug., 296–299). The author touches on many of the chemical engineering problems involved in iron and steelmaking and indicates some of the future trends in the industry. The relative merits of Bessemer and O.H. furnace techniques are discussed and research on Bessemer converter design and operation to avoid slopping is described. The problems involved in stirring metal and slag, in desulphurization of fuel, in duplexing, in mixers and ladles, in sulphur removal, etc., are outlined. The author concludes with some remarks on electric furnaces.—L. E. W.

**Development and Improvement of Steelmaking Plant and Processes: Current Projects Under Investigation in the U.K.** (*Iron Coal Trades Rev.*, 1955, **170**, June 10, 1341–1344). An outline is given of some of the research and development projects being studied by B.I.S.R.A. committees. They include operational research, oil-burner investigations, oxygen steelmaking, pyrometry, gas flow, electrode consumption, ingots and ingot moulds, and rolling techniques.—G. F.

**Noise Measurement for the Supervision and Control of the Blast in the Converter Process.** J. Klärding. (*Metall*, 1955, **9**, Sept., 780–783). It is shown that noise intensity during the converter blowing stage varies in a manner characteristic of the oxidation processes. A comparison of noise record charts enables one to analyse successive charges. Characteristic changes in the noise intensity, e.g. when the oxidation of phosphorus begins, can be made to actuate electric signals facilitating the control of the process by the operating crew.

**Development of the Blast Process for Steel Production.** O. Cuscoleca. (*Oesterreichische Chemiker-Zeitung*, 1955, **56**, (13–14), 187–198). A process for steel production is described, using oxygen and a minimum amount of scrap. The following advantages are claimed: good quality, low initial cost, low running cost, continuous production, small scrap additions.

**Observations through the Tuyeres of a Blowing Converter. Influence of Local High Temperatures on Chemical Processes.** G. Naeser, W. Pepperhoff, and H. Riedel. (*Stahl u. Eisen*, 1955, **75**, Sept. 22, 1244–1249). During continuous measurement of the bath temperature in a blowing converter by observation through a tuyere, two disturbances occur and their cause has been clarified. Often, during the first half of the blow, solid accretions form on the mouths of the tuyeres and these disappear after a few minutes. These accretions are composed of 'frozen-on' pig iron, the carbon content of which is less than that of the rest of the bath, owing to the rapid reactions in the regions of the tuyeres. With oxygen-enriched air blows, there occur local high temperatures, hundreds of degrees above the 'mean' melt temperature. The incoming oxygen–air mixture reacts violently with the melt surface and produces high temperatures in so short a time that equilibrium with the bulk of the metal cannot be attained. The possible effect of these high temperatures on nitrogen pick-up is discussed. Laboratory investigations have shown that nitrous oxide can be formed by blowing an air–oxygen mixture on to molten iron and that the amount formed increases as the oxygen content is raised. Nitrous oxide reacts with iron to give a marked nitrogen absorption. The presence of moisture (4–6%) suppresses the formation of nitrous oxide. It thus appears that formation of this gas at high temperatures can influence nitrogen pick-up.—J. P.

**New Method of Measuring Flow Turbulence.** Yu. N. Tulуevskii. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 74–77). [In Russian]. The flow-visualization method described is especially suitable for model studies on O.H. and other metallurgical furnaces. It is a modification of the Dvorjak technique in which a thin heated wire is inserted in the stream, the change in density of the fluid passing over it causing a shadow to be thrown on a screen. From this the turbulence of the flow can be evaluated. The theory of the method is given together with results of tests by which its validity was established.—S. K.

**Should one Build All-Basic Open-Hearth Furnaces?** O. Bohuš. (*Hutník*, (Prague), 1955, **5**, (11), 323–325). [In Czech]. The economics of silica and chrome-magnesite roofs are considered. These favour the all-basic roof.—P. F.

**Tractors Speed Openhearth Rebuilding.** (*Iron Age*, 1955, **176**, Sept. 15, 146). The use of tractors in demolishing and rebuilding O.H. furnaces at Granite City Steel Co., Ill., is described. Demolition is started within 1 h of shutdown and completed in 4 h. A wheeled tractor helps the rebuild.

**Report of the Constitution of Charge Subcommittee.** (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (10), 1974–1977). Recommendations are given on the use of both hot and cold pig iron. The use of the hot-blast cupola for melting scrap prior to the open-hearth, as practised in Belgium and Germany, is outlined.—T. E. D.

**Charging Open Hearth Furnaces.** R. Solt. (*Brit. Steelmaker*, 1955, **21**, Sept., 294–297, 304). The author discusses the problems involved in ensuring a constant flow of materials to O.H. furnaces. Two independent factors are assessed; firstly, the demand of the furnaces and its variation from time to time, and secondly, the ability of the supply system to meet different levels of demand.—G. F.

**Calculating the Charge Composition leading to a Required Carbon Content upon Melting in 200-ton Open-hearth Furnaces.** J. Bečvár. (*Hutník*, (*Prague*), 1955, **5**, (8), 232–234). [In Czech].

**Elimination of Carbon in the Open Hearth Furnace. I.** P. Vallet. (*Iron Steel*, 1955, **28**, Oct., 463–467). The author attempts to collate established experimental data and theories concerning the mechanism of decarburization. Carbon–oxygen equilibrium and excess oxygen are discussed, and the formation of CO bubbles is considered. A kinetic theory is developed, assuming that rate of carbon drop is governed by the rate of CO formation at the gas/liquid interface. The data indicate that carbon elimination is diffusion-controlled.

**Physical Chemistry Applied to Iron and Steelmaking.** P. Vallet. (*IRSID, Centre d'Études Supérieures de la Sidérurgie*, Metz, 1954, *Les Cahiers du Cessid*, No. 20, pp. 240). In each chapter the general theories are presented and then applied to problems of iron and steelmaking. Results obtained from published literature are used in the discussions. The subjects covered are: (i) the liquid state; (ii) the thermodynamics of solutions and its applications to alloys and liquid slags; (iii) study of the Fe–O–Mn system; (iv) study of the Fe–O–Mn–Si system in the presence of solid silicon; (v) kinetic chemistry; (vi) decarburization, including a static study of the system Fe–O–C and a kinetic study of decarburizing in the O.H.; (vii) solution of gas in iron and steel, and elimination of dissolved gases by release of a gaseous reaction product.

**Ore or Mill Scale as Decarburizing Agent in the Steel Furnace.** E. Plettinger. (*Radex Rundschau*, 1955, May/June, 409–417). Principles of decarburization are discussed and the merits and uses of iron ore and mill scale as decarburizing agents are considered. Iron ores are preferred because their higher purity and lower water content have a considerable influence on production economy and product quality.—E. C.

**Commercially Pure Iron.** E. N. Simons. (*Canad. Min. J.*, 1955, **76**, July, 66–67). Care must be taken in choice of raw materials. The O.H. method, in which hematite is added to the molten iron, and the electrolytic process are discussed. Properties are given.—T. E. D.

**Application of Pre-refining to Thomas Iron.** Bauer. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (9), 1773–1785). The blast-furnaces of Forges et Aciéries de Dilling produce

iron with a high and erratic $SiO_2$ content. Pre-refining with pure oxygen reduces the $SiO_2$ content to a lower, more constant level. Sufficient oxygen is available from a new plant. The water-cooled oxygen lance is described; oxygen pressure is 12 kg/cm². The pre-refining procedure is described, and results of trials are reported. Final Si content depends on initial content and on oxygen consumption. The life of converter bottoms, and possibly of the sides, is lengthened as a result of the smaller Si content of the charge.—T. E. D.

**Various Methods of Desulphurizing and Desiliconizing in Steelmaking.** (*Iron Coal Trades Rev.*, 1955, **171**, July 22, 201–208; July 29, 253–260; Aug. 5, 319–323). After an outline of the general problems, this review deals firstly with desulphurization of ironmaking raw materials, including the effects of agglomeration methods. The mechanism of desulphurization in the blast-furnace, and factors affecting it, are next considered. Means of improving the efficiency and the effects of acid burdening are also discussed. Methods of desulphurizing molten iron which are considered are: runner or transfer ladle treatments; rotary furnace (Kalling) process; metallic additions; and inactive and active mixer practice. In considering desulphurizing in the steelmaking process, the effects of slag/metal conditions, furnace atmosphere, and bath metallic additions are discussed, and launder or ladle treatments using solid lime, pre-melted synthetic slags, or metallic additions are described. The section on desiliconization begins with blast-furnace practice in producing low-silicon iron, followed by details of experiments at Brymbo, Margam, Dorman Long, and Oberhausen on ladle treatment of molten iron. The Oberhausen ' rotor ' process is also discussed.—G. F.

**Studies on a 10-cwt Arc Furnace.** W. H. Glaisher, M. Preston, and J. Ravenscroft. (*J. Iron Steel Inst.*, 1956, **183**, May, 22–41).

**Some Factors Affecting Electrode Consumption in the Electric Arc Furnace.** D. H. Houseman. (*J. Iron Steel Inst.*, 1956, **183**, May, 48–53). [This issue].

**Addition of Special Minor Elements to Electric Furnace Heats.** C. W. Sherman. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 182–183). The author formulates a general method of approach in setting up a recommended practice for the addition of special elements in electric steelmaking, taking resulphurization, rephosphorization, and special deoxidation as examples. Mechanical devices which can assist in the use of the special elements are also considered.—G. F.

**Basic Electric Melting Practice for Quality Steel.** A. F. Gross. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 89–107). The author gives details of the basic electric practice developed at Ohio Steel Foundry Co. for the production of quality steels, describing the furnaces and the charging, melting, oxygen-blowing, and tapping procedures. The effects of certain variables and mechanical properties of the finished casting are correlated, and in particular the necessity for avoiding delays and for reducing gas contents is emphasized.—G. F.

**Comparative Economics of Open-Hearth and Electric Furnaces for Production of Low Carbon Steel.** S. L. Case, D. D. Moore, C. E. Sims, and R. J. Lund. (The Electric Furnace Survey Group, comprised of fourteen electric utility companies and Bituminous Coal Research, Inc., 1953). This is a critical appraisal of the present and potential competitive aspects of electric furnace and O.H. processes for production of plain carbon steels containing up to 0·25% C. The technical and economic advantages and disadvantages of each process are surveyed for modern plants of three sizes (250,000, 500,000, and 1,000,000 tons annual capacity) and for both cold metal and 50/50 hot-metal/cold-metal practices. Comparisons are first made of modern shops and steelmaking practices, including material and heat balances, followed by data on capital and steelmaking costs. Performance and steel quality characteristics of the two types of melting shop are then considered. A comparison of probable steelmaking costs of the future is also made, and some important factors in future costs, including fuels, electrodes, steel scrap, hot metal, and electric power, are discussed at length. The comparative economics show that capital costs are appreciably in favour of electric melting shops. Net production costs are in favour of the electric furnace for cold-metal practice, but the position is reversed for hot-metal practice. Returns on capital invested should be similar for both shops in hot-metal practice, but with cold-metal practice the electric shop should yield higher returns. The entire analysis should be used mainly as a guide for similar studies based on actual data for a given set of localized conditions.—G. F.

**Coreless Mains Frequency Melting is Revived.** F. S. Leigh. (*Metalworking Prod.*, 1955, **99**, Nov. 25, 2004–2007). The basic principles of coreless mains-frequency induction heating for melting furnaces have been known for a long time, but were abandoned as unsatisfactory. Recent independent work by Birlec Ltd. in England, Otto Junker G.m.b.H. in Germany, and Ajax Engineering Corp. in the U.S.A. has led to the revival and application of the principles for melting. These have proved successful and considerable economies are claimed in the right circumstances.—M. A. K.

**A 1000-lbs. Vacuum-melting Furnace.** (*Machinery*, 1955, **87**, Dec. 30, 1526–1528). This furnace which has recently been installed by the Carboloy Dept. of the General Electric Co., U.S.A., will produce two 1000-lb melts per shift. Two operators are normally employed. The design of the furnace and the arrangement for handling moulds for pouring are described. Brief reference is made to some of the possibilities of vacuum melting.—M. A. K.

**Low-Frequency Induction Melting and Heating.** R. K. Treloar. (*Australian Inst. Metals: Australasian Eng.*, 1955, June 7, 62–69). The general principle of induced current at low frequency (50–60 cycles) as a means of heating is broadly reviewed. An outline is given of the history and development of low-frequency melting furnaces, and the designs and applications of several units now available in Australia are described. Low-frequency billet heating for hot working is also briefly discussed.—P. M. C.

**The Efficiency of Coreless Induction Furnaces.** H. Hess. (*Elektrowärme-Techn.*, 1955, **6**, July-Aug., 133–138). The efficiency of low-frequency melting furnaces with a crucible capacity of 1 ton or more is compared with similar H.F. furnaces. Developments foreshadowed by the author should determine a trend towards a wider use of mains frequency furnaces, down to 10-in. bath diameters, as these would become more efficient and cheaper to install.—P. F.

**Rate of Desulphurization of Molten Iron by Slag under Reducing Condition.** T. Saitô and Y. Kawai. (*Sci. Rep. Res. Inst. Tohoku Univ.*, A, 1955, **7**, Aug., 402–410). The rate of transfer of sulphur across a metal/slag interface under reducing conditions was studied in the range 1440–1570° C. This was satisfactorily interpreted as a first-order reaction, provided the slags were highly viscous. In the case of low-viscosity slags the transfer rate was profoundly influenced by side reaction. The higher the temperature and the more basic the slag, the higher the rate of transfer.—J. G. W.

**Slag Control in Steelmaking.** W. Küntscher. (*Metallurgie*, 1955, **5**, Aug., 241–245). Slag control procedure needs improvement. It may be possible to increase the reactivity of slags by adding small amounts of halogen salts to improve toughness and wettability.—L. J. L.

**Phase Equilibria in the System $FeO$–$Fe_2O_3$–$SiO_2$.** A. Muan. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Sept., Section 1, 965–976). The author presents liquidus data for mixtures in the $FeO$–$Fe_2O_3$–$SiO_2$ ternary system in equilibrium with a gas phase with varying oxygen partial pressures. The data obtained are combined with published data to construct lines of equal oxygen partial pressures and of equal $CO_2/H_2$ mixing ratios along the liquidus surface. Courses of crystallization of selected mixtures are discussed.

**Basic Slag in Steel Production: General Examination of its Composition and Function using a Simplified Technique.** D. J. O. Brandt. (*Iron Coal Trades Rev.*, 1955, **171**, Aug. 19, 435–442). The author discusses the formation and function of the slag in basic steelmaking and, using certain simplifications, demonstrates a technique whereby a reasonable approximation to the whole essential chemistry of all basic slags may be outlined. The effects of carbon removal and the chemistry of desulphurization and dephosphorization are considered.—G. F.

**Effect of Suspending the Ingot during Trumpet Teeming on the Formation of Transverse Cracks.** Ya. L. Troskunov, A. M. Ofengenden, and I. I. Bekker. (*Stal*, 1955, (2), 133–136). [In Russian]. Factors influencing the ease of withdrawal of trumpet-teemed O.H. steel ingots from moulds have been studied experimentally. The main obstacle to withdrawal was found to be the wedging of the tail runner in the bottom sleeve. Chamfering the top of the mould produced a lip on the ingot which prevented the settling of the latter on the

mould bottom and greatly facilitated withdrawal. The thickness of the ingot crust was sufficient to support the weight of the ingot by the lip and no cracks were formed. The causes of crack formation in ingots have been considered.—S. K.

**Improvement in the Life of Teeming Stoppers.** L. M. Pokrass and Z. I. Kodryanskii. (*Stal*, 1955, (2), 180–181). [In Russian]. An account is given of developments in the design of teeming stoppers which have led to great reductions in metal loss.—S. K.

**Pioneering in New Developments in a Specialty Steel Mill.** H. G. De Young. (*Iron Steel Eng.*, 1955, **32**, July, 114–118); **Continuous Casting Installation for Stainless and Alloy Steels.** (*Engineer*, 1955, **200**, Sept. 9, 383–384). Details are given of the revolutionary steel-mill plant installed at the Welland Works of Atlas Steels Ltd., in Ontario, which has now been in operation for six months. The equipment includes a Rossi–Junghans continuous slab casting machine, a Linde powder scarfing machine, a hot Sendzimir mill, and an electrolytic salt descaling line.—M. D. J. B.

**Mottled Segregation and Laminar Fracture in Steel.** N. K. Ipatov, M. I. Kolosov, and P. P. Mukhina. (*Stal*, 1955, (3), 261–267). [In Russian]. This is a critical discussion of recently published work on the effects of mottled segregation and laminar fracture which appear in some carbon and alloy steels but never in some Ni-containing steels. It is based on experimental work and production experience at the Chelyabinsk works in which distribution of mottled segregation along ingots from steel killed under different conditions, the chemical composition of the spots, and the microstructures of segregation-affected areas were studied, and detailed investigations were made on microstructures in regions adjoining laminar fractures.—S. K.

**New Developments in Exothermic Hot Topping of Ingots.** M. Bock II. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 163–169). The exothermic materials dealt with are mainly Al-based, either of the thermit metal-producing type or of the non-metal-producing type which draws its reaction oxygen mainly from the atmosphere. The methods of using them are discussed and typical results illustrating the appreciable increased yield are given. Insulating and carbonaceous materials are also referred to briefly.

**Use of Mould Dressings in Steelmaking.** D. R. Thornton. (*Brit. Steelmaker*, 1955, **21**, Aug., 252–257). The author discusses the occurrence of ingot surface defects and considers some of the factors affecting ingot surface quality, including type of steel, teeming temperature and speed, condition of mould, and use of mould dressing. The properties and functions of the various dressings are described and their use in practice is outlined.—G. F.

**The Effects of Gravity in the Solidification of Steel.** B. Gray. (*J. Iron Steel Inst.*, 1956, **182**, April, 366–374).

## PRODUCTION OF FERRO-ALLOYS

**Zirconium and Zirconium Alloys.** (*Tek. Tidskr.*, 1955, **85**, Aug. 9, 633–636). [In Swedish]. A review of recent advances in manufacturing techniques deals with the Kroll and fused salt electrolysis methods; separation from hafnium by crystallization, ether extraction, and ion exchange; double melting to improve purity and the melting, moulding, drawing and heat treatment of zirconium. Mechanical strength characteristics of Zr alloys are also discussed.—G. G. K.

**Some Factors Influencing the Production of Manganese from Open Hearth Slag by the Two-Stage Process with Special Reference to Certain Properties of the Slag.** H. W. Hosking. (*Australian Inst. Metals: Australasian Eng.*, 1955, Mar. 7, 70–75). The successful operation of the two-stage process (described in earlier papers) is shown to be dependent to a large extent on control of the fusion points, viscosities, and thermal and electrical conductivities of the slags involved. Individual aspects of the process which may be affected by these properties are itemized, and means of control are indicated. Further research of a fundamental nature is shown to be necessary for a full appreciation of the issues raised and a project of this nature is foreshadowed.—P. M. C.

## FOUNDRY PRACTICE

**The Bases for Evaluating Requirements for Hygiene and Accident Prevention in Projecting and Equipping Foundries.** J. Mejstřík. (*Slévárenství*, 1955, **3**, (12), 391–395). [In Czech].

**Introduction to the Visit to the N.V. "De Globe," Tegelen.** F. Van Bergen. (*Metalen*, 1955, **10**, Nov. 30, 475–478). [In Dutch]. The author describes for the information of visitors the activities of the N.V. De Globe foundries at Tegelen and Belfeld in Holland, illustrating his remarks with several drawings showing the layout of the plant.—F. R. H.

**Colour Coding of Foundry Equipment.** P. Fagerström and R. Orban. (*Gjuteriet*, 1955, **45**, Oct., 139–143). [In Swedish]. The advantages of standard colours for use when painting various items of foundry equipment are reviewed—especially from the safety angle—and examples are shown of applications in Swedish foundries.—G. G. K.

**Foundry Noise and Its Control.** H. T. Walworth. (*Amer. Foundryman*, 1955, **27**, May, 104–109). The problem of noise in relation to foundry work is discussed and methods for reducing the noise level and for providing personal protection against excess noise are considered.—B. C. W.

**New Proposals for a Standardization of Gray Cast Iron.** A. Collaud. (*Roll'schen Eisenwerke, Mitt.*, 1954, **13**, July-Dec., 75–97). It is proposed that the standard specifications should indicate the properties of the casting itself. The castings were divided into 5 classes: very thin, very light castings; thin and light castings; castings of medium wall thickness and weight; heavy and thick; and very heavy and very thick castings. The conditions of cooling and strength were used as co-ordinates in a number of diagrams. These diagrams will give the desired properties of a casting with sufficient accuracy: transverse rupture stress, modulus of elasticity at beginning of the load, Brinell hardness, elastic limit, ductility, toughness, etc.—U. E.

**Discussion on Systems and Equipment for the Mechanization of Foundries.** W. Horth *et al.* (*Bol. Assoc. Brasil. Met.*, 1955, **11**, Apr., 161–236. [In Portuguese]. This subject is treated under seven headings, as follows: (*a*) the reclamation of foundry sands, (*b*) the mechanization of a modern foundry, (*c*) tunnel machines for the treatment of castings by sand and shot blasting, (*d*) the process of shell-moulding and Durez resin, (*e*) some solutions of the problem of foundry mechanization, (*f*) mechanization of the cleaning of castings, (*g*) methods and equipment for the mechanization of ferrous foundries.

**Safety in Foundry Practice.** H. Karig. (*Giessereitechn.*, 1955, **1**, Sept., 157–158).

**Results of Metallurgical Studies of the M.B.C. and ADS Cupolas.** A. De Sy, R. Doat, R. Balon, L. Winandy. (*Inst. Brit. Found.*, 1955, June 20–24, Paper No. 1127). The results of tests on two different types of cupolas are presented and discussed in detail. The M.B.C. is a water-cooled cupola operating on hot blast under reducing conditions which can melt 100% steel scrap, while the ADS cupola is a basic-lined, cold-blast, water-cooled furnace which uses 40–100% steel scrap. Both cupolas produce cast iron of controlled composition but in the ADS furnace it is only possible to control C and S, while in the M.B.C., C, Mn, Si, S, and P may be controlled.—B. C. W.

**Measuring the Blast Volume in the Cupola.** Z. Gause. (*Slévárenství*, 1955, **3**, (12), 388–390). [In Czech].

**Present Day Melting Practice and the Use of Fuel in the Foundry.** J. W. Grant. (*Brit. C.I. Res. Assoc., J. Res. Dev.*, 1955, **6**, Oct., 56–59).

**The Development of Measuring and Regulating Techniques for Hot-Blast Cupola Plants.** F. Von Mertz. (*Giesserei*, 1955, **42**, Sept. 29, 549–551). This is a review article of the measuring and regulating methods available for hot-blast cupolas. In particular, the measurement of volume, pressure and temperature of the hot blast, of the exit gases, and the throat gases are described, and the measurement of $CO/CO_2$ ratio. The level of the charge can be measured using a photocell.—R. J. W.

**The Sulphur Index as a Function of Slag Composition in a Philipon Furnace.** J. Drachmann. (*Gjuteriet*, 1955, **45**, July, 89–95). [In Swedish]. By statistical studies of slag and iron analyses for cold- and hot-blast cupolas the author shows that although there is good correlation between the basicity and sulphur indexes, the equilibria are not reached owing to inadequate contact time between the iron and slag. Of the slag components, FeO and MnO exert no direct influence on the sulphur index, whilst the $Al_2O_3$ present has only a slight effect as compared with that of $SiO_2$ and CaO. Thus the basicity index $CaO/SiO_2$ gives a good measure of the influence of slag composition on the sulphur index.—G. G. K.

**Chemical Reactions in the Cupola.** G. A. H. Jungbluth and K. Stockkamp. (*Inst. Brit. Found.*, 1955, June 20–24, Paper No. 1125). The thermodynamic principles governing cupola

reactions are discussed and detailed consideration is given to the behaviour of iron oxide, Si, Mn, and S. The agreement between theory and practice has been studied by carrying out 28 experimental melts in a small hot-blast cupola and the results of this investigation are discussed in detail. Among the aspects considered are the effects of blast temperature on the combustion temperature of the coke, the combustion rate, the iron temperatures, the FeO distribution between metal and slag, and the Si, Mn, P, and S contents of the metal.—B. C. W.

**Study on the Hardening of Cast Iron. II. Quenched Structure of Cast Iron by Induction Heating.** K. Okabayashi. (*Nippon Kinzoku Gakkai-Si*, 1953, **17**, Apr., 167–171). [In Japanese]. The martensite of cast iron treated by induction hardening is finer than that in quenched iron, and is very hard. The short heating time is liable to lead to lamellar $Fe_3C$ being retained in the matrix. The graphite is often overheated at the circumference of the particles, and may be abnormally expanded. A pearlitic matrix is preferable.—K. E. J.

**Magnesium-Ferrous Castings Solve Design Problems.** H. W. Crusey. (*Mat. Methods*, 1955, **41**, May, 114–115). Fairchild Engine and Airplane Corp. have developed a method of bending steel and magnesium. This 'Fer-Mag' construction is ideal where weight is at a premium. Typical examples, including the bonding of a steel hub in a magnesium flywheel and stainless-steel tubing systems in solid castings, are described.—P. M. C.

**The Correct Impregnation of Castings.** P. M. Young. (*Eng. Insp.*, 1954–55, **18**, Winter, 90–94)). The sealing of microporosity, particularly in light alloy castings, by internal, external, and batch-type vacuum-pressure techniques is described. The uses and disadvantages of various early impregnating materials—sodium silicate, tung oil, synthetic resins—are discussed, and the eventual development of a styrene polyester-type resin with good impregnating ability and resistance to metal-finishing solutions, boiling water, steam, and corrosive action is outlined.—P. M. C.

**Metal Oxide Sealer Effectively Impregnates Castings.** W. J. Grassby. (*Iron Age*, 1955, **176**, Sept. 15, 135–137). A process for impregnating Al diecastings with a metal-oxide sealer is described. The seal reacts with the parent metal in the micropores, and the casting is impervious up to 2100 lb/in².

**A New Method for Determining the Tendency to the Formation of Shrinkage Cavities.** V. Oliverius and J. Vaculík. (*Slévárenství*, 1955, **3**, (9), 269–272). [In Czech]. Current methods for assessing the liability to the formation of shrinkage cavities are reviewed and found inadequate. A satisfactory method, developed by the Brno Foundry Research Institute, is described. It depends upon a rapid gravimetric determination of pipe in test cylinders cast into small standardized moulds.—P. F.

**The Effect of Feed Velocity of Liquid Metal on the Quality of the Internal Structure of Castings.** S. Šimoník. (*Slévárenství*, 1955, **3**, (9), 258–260). [In Czech]. For sound castings the feed velocity must be increased if shrinkage and solidification rates are high. Velocities are limited by the hydraulic resistance of interdendritic channels but can be increased by the application of pressure.—P. F.

**Metal and Mould Research on Steel Castings. I—Solidification Mechanism.** J. A. Reynolds and A. Preece. **II—Mould- and Core-bonding Agents.** J. M. Middleton and J. White. (*Inst. Brit. Found.*, 1955, June 20–24, Paper No. 1123). Part I: The factors controlling macroporosity in steel castings and the use of thermal analysis techniques and wax models in studying solidification are discussed. Experiments with stearin wax suggested that there might be a relation between crystal structure and microporosity, and this was confirmed by experiments on steel castings, which also showed that microporosity was responsible for low ductility in tensile test pieces. The mechanism of crystal growth in steel castings is discussed, and it is suggested that a macrostructure consisting of a shell of columnar crystals and a core of large uniaxed crystals will give the best mechanical properties. Methods of obtaining this type of structure are briefly summarized. Part II: The constitution and properties of bonding clays are discussed and detailed results are given of the bonding properties of 22 bentonites and 12 British clays. The complete replacement of bentonite by British clay does not appear to be feasible, but results are given to show that partial replacement holds distinct possibilities. An accelerated 'life' test for bonding clays is described and data obtained with a number of bentonite and kaolinite clays are given. Di-electric-cured and oven-baked resin-bonded cores are then compared and their relative susceptibilities to moisture pick-up are investigated. The incidence of hot-tearing in steel castings is shown to be influenced by the degree of ramming and by the type and amount of bond employed in the moulding material.—B. C. W.

## REHEATING FURNACES AND SOAKING PITS

**Jointed Metal Furnace Hearths and Regulators (System Javelle).** (*Aciers Fins Spéc. Franç.*, 1955, Nov., 66–70). A brief description is given of a metallic type of furnace hearth, consisting of an assembly of cast steel plates. Applications of this type of hearth are discussed, and reference is also made to furnace regulators constructed on the same principle.

**New Battery of Soaking Pits at Longwy Works (Mont-St-Martin Section) of the Société Lorraine-Escaut.** Boitel. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (10), 1983–1987). The battery consists of independent 60-ton units, 6 m long × 2·6 m wide × 3·5 m high, with mechanical covers moving longitudinally. Heating is by means of one Stein–Chapman burner per pit using pure blast-furnace gas, with the possibility of coke-oven gas addition. The recuperator construction, heating cycle and method of regulation are described.—T. E. D.

**Steel Industry Modernizes and Expands.** (*Indust. Heating*, 1955, **22**, June, 1203–1216). The applications of cast alloys containing Ni and Cr for heat-resistant parts of annealing furnaces, soaking pits, and metallic recuperators are described with reference to modern U.S. plant.—A. D. H.

**Continuous Car Bottom Furnaces.** W. J. Assel. (*Indust. Heating*, 1955, **22**, Apr., 732–738, 746). Continuous car bottom furnaces are compared with roller hearth, rotating hearth, and pusher type furnaces. A furnace installed at Timken Roller Bearing Co., Ohio, is described.—A. D. H.

**Successful Modernization of Soaking Pits.** H. W. Hodges. (*Indust. Heating*, 1955, **22**, May, 983–986). The benefits achieved by increasing the size of soaking pits which were then instrumented are described.—A. D. H.

**Sixty-Cycle Induction Heating of Large Steel Sections for Hot Forming.** C. H. Hartwig. (Amer. Soc. Mech. Eng.: *Indust. Heating*, 1954, **21**, Sept., 1732–1734, 1880–1882; Dec., 2522–2530; 1955, **22**, Jan., 46–48, 190–194; May, 952–958; June, 1160–1166). The theory of induction heating is outlined and pilot-plant equipment for the heating of 8 in. × 8 in. ingots of carbon, silicon, stainless, and tool steels are described. Temperature, current, and power curves are presented.

**Design Aspects of High Frequency Heaters.** D. W. Warburton-Brown. (*Machinery Lloyd.* European Ed., 1955, **27**, May, 37–44). The design of H.F. induction heating equipment of the valve oscillator type is discussed.—B. G. B.

## HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

**Short Cycle Heat Treatment Improves Low Alloy Pipe Production.** J. Kniveton. (*J. Met.*, 1955, **7**, Nov., Sect. 1, 1172–1177). The advent of short-cycle heat-treatment has permitted the production of oil-well piping from lower-alloy steels without sacrifice of quality and properties. The short-cycle cylindrical gas-fired furnace developed by Selas Corp. of America is described, and brief details are given of the operation of the equipment in a number of works.—G. F.

**Heat Treating Equipment and Procedures.** C. L. Ipsen. (*Metal Progress*, 1955, **68**, Sept., 106–109). Recent advances in the heat treating of steel are discussed. The development of controlled atmospheres, induction heating, and mechanization have contributed most to the improvements.—B. G. B.

**Low Voltage Nickel Chromium Elements for Heat Treatment.** (*Canad. Metals*, 1955, **18**, Nov., 22–23). A short account of the use of corrugated sheets of Ni–Cr as elements in electric heating furnaces is presented.—B. G. B.

**Mechanized Heat Treatment of Grey Iron Castings.** (*Canad. Metals*, 1955, **18**, Sept., 46–48). A short account of the use of a direct gas fired furnace is given.—B. G. B.

**Heat Treatments in Controlled Atmospheres.** E. G. De Coriolis. (*Métaux–Corrosion–Indust.*, 1955, **30**, Oct., 365–378). The principles of gas generators for this use are explained with diagrams. Gaseous cementation is considered and the

fundamental factors controlling efficient cementation are described together with commercial equipment. The replacement of carbon in decarburized surface layers is also considered.—B. G. B.

**Heat Treating: Rx For Better Machinability.** F. J. Robbins J. J. Lawless. (*Iron Age*, 1955, **116**, Sept. 1, 94–97). This article, based on shop experience, tells how heat treating provides better machinability. The influence of variables in steel are considered in turn.—D. L. C. P.

**Metals "Custom-Tailored" Through Controlled Heat Treating.** J. J. Kennedy. (*Metal Treating*, 1955, **6**, July-Aug., 16–18, 39). The importance of temperature control in heat-treatment processes is the theme of this article. Some typical systems of instrumentation (all using Honeywell Brown equipment) are described.—P. M. C.

**How To Avoid Heat Treating Difficulties Through Correct Design of Press Tools.** F. Strasser. (*Metal Treating*, 1955, **6**, Jan.-Feb., 2–4, 6, 8, 10). The basic causes of failure in heat-treatment of die members are stated to be incorrect design and improper selection of steel grade. Good and bad die design is discussed in detail and the importance of the distribution of holes, avoidance of sharp corners, changes in section thickness, etc., is dealt with.—P. M. C.

**Cooperation Between the Heat Treater and the Steel Manufacturer.** C. B. Post. (*Metal Treating*, 1955, **6**, Jan.-Feb., 24–27). The author discusses the manufacture and heat-treatment of tools. Several case histories are discussed which illustrate failures of tools and other components due to poor design, poor machining, incorrect steel quality, and incorrect heat-treatment procedure.—P. M. C.

**Instrumentation for Atmosphere Analysis and Control.** W. L. Besselman. (*Indust. Heating*, 1955, **22**, Apr., 704–712). The application of thermal conductivity and infra-red methods of gas analysis to the control of exothermic, endothermic, and dissociated ammonia atmospheres is described. Safety precautions in plant operation are discussed.—A. D. H.

**Dry Nitrogen-Base Prepared Atmospheres.** D. Beggs. (*Indust. Heating*, 1955, **22**, Mar., 526–538). The preparation of atmospheres rich in $N_2$ (*a*) by partial combustion of fuel gas, (*b*) from ammonia and air, and (*c*) from by-product $N_2$ is described. The application of these atmospheres in controlled atmospheres is briefly outlined.—A. D. H.

**Continuous Automatic Unit for Heat Treating Torque Converter Shafts at Chrysler Plant.** A. R. Robertson. (*Indust. Heating*, 1955, **22**, Mar., 480–488). Furnaces and auxilliary equipment for the automatic heat-treatment of shafts are described in detail. The operations include hardening in a radiant-tube furnace, oil quenching, degreasing, and tempering in a recirculating-type furnace. The plant can be used for gas carburizing.—A. D. H.

**Future Needs Specify Heat Treating Requirements for New General Electric Metals and Ceramic Laboratory.** M. A. Cocca. (*Indust. Heating*, 1955, **22**, Aug., 1556–1568, 1718–1726). Furnaces and heat-treatment equipment used in a large development laboratory are described.—A. D. H.

**Gas Carburising Practice.** L. G. W. Polethorpe. (*Wild Barfield Heat Treatment J.*, 1955, **5**, Sept., 2–7). Typical gas carburizing furnaces are briefly described. The two principal gas carburizing techniques available (the drip feed and generator gas methods) are compared.—D. H.

**Apparatus for the Thermoelectric Investigation of Diffusion Layers.** A. K. Bescrovnyĭ. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 109–110). [In Russian]. The study of the thickness and composition of the case-hardened layer in steel by a thermoelectric method is described. A section in depth is taken from the steel and immersed in a non-conducting liquid at 100° C. Two identical pointed contacts touch the surface, the difference in potential being a measure of the difference in composition at the two points of contact. The results agree well with those of chemical analysis. Calibration curves for an alloy steel are given. The method is particularly suitable for martensitic steels.—S. K.

**Machine for Determining the Quality of Case-Hardening.** I. P. Vyazovoi. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 110–112). [In Russian]. In the testing machine described the depth of the case-hardened layer is found from the force required to remove a rod of ferromagnetic material from contact with the tested surface in a magnetic field. It is especially suitable for the quality control of gear-wheels, after H.F. surface hardening.—S. K.

**Pros and Cons of Carbon Restoration.** P. M. Unterweiser. (*Iron Age*, 1955, **176**, Sept. 8, 71–73). The advantages and limitations of carbon restoration to decarburized parts are discussed. Conditions leading to carbon deficiency are noted and methods of restoration surveyed. Success depends on the type of steel, correct equipment, and good control.—D. L. C. P.

**Structure and Hardness of the Hardened Layer in the Surface Hardening of Steel with an Oxygen–Paraffin Flame.** A. M. Glikshtern. (*Avtog. Delo*, 1953, (6), 10–12). [In Russian]. Various conclusions are drawn from an investigation of the structure and hardness at various depths in a structural steel surface-hardened with an oxygen–paraffin flame.—S. K.

**Multiflame Hardening Torch MZG-49.** (*Avtog. Delo*, 1953, (3), 31–32). [In Russian]. A brief account is given of the design and characteristics of an oxyacetylene surface-hardening torch developed in the U.S.S.R.—S. K.

**The Induction Hardening Process and its Application.** H. Voss. (*Schweissen u. Schneiden*, 1954, **6**, Special Issue, 173–180).

**The Use of Induction Heating for Stress-Relieving in Large, Welded Tubes.** H. J. Henninger, F. Alf, and F. Seiffe. (*BWK*, 1955, **7**, Oct., 445–449). Stress relieving of 11-ft. dia. electrically welded steel duct by means of 50- and 200-c/s generators is described.—P. F.

**Large Scale Continuous Annealing of Coils with Carbon Restoration.** (*Indust. Heating*, 1955, **22**, Sept., 1770–1778, 1934–1938). A furnace for annealing wire in an atmosphere which makes good previous surface decarburization is described. It is heated in six zones by suction-type gas-heated radiant tubes. Emergency equipment is provided in case of failure.—A. D. H.

**Electric Furnaces for Spheroidizing: Tubes, Ltd., Installation at Kirby Muxloe.** (*Iron Steel*, 1955, **28**, Oct., 484). Details are given of the five batch-type spheroidizing furnaces supplied to the Kirby Muxloe works of Tubes Ltd. by G.W.B. Furnaces Ltd. Each furnace is heated by resistance elements in four independent zones, and is fitted with a comprehensive system of temperature control.—G. F.

**Electric Furnaces For Spheroidizing.** (*Wild Barfield Heat Treatment J.*, 1955, **5**, Sept., 9). An electric furnace installation is briefly described designed for the spheroidizing of ball-bearing and ball-race steels.—D. H.

## FORGING, STAMPING, DRAWING, AND PRESSING

**Heavy Press Developments.** (*Welding Metal Fab.*, 1955, **23**, Nov., 417–419). Several heavy presses are described, a new 3000-ton heavy-duty plate bending press made by Hugh Smith and Co. (Possil) Ltd., a 2000-ton Fielding and Platt press, and an 8000-ton hydraulic-beam press capable of bending 8-in. thick hot plate, which is installed at the Foster Wheeler Mountaintop works in the U.S.A.—U. E.

**Short Run Press-Formed Parts.** M. W. Riley. (*Mat. Methods*, 1955, **41**, Mar., 121–136). A comprehensive survey is presented of press-forming methods available for short-run sheet-metal part production. Such methods include forming with rubber pads, deep drawing with flexible female dies, drawing and embossing with flexible punches, and drop-hammer forming. Advantages, limitations, and capabilities of the various methods are discussed.—P. M.C.

**Russia Automates Nut and Bolt Production.** (*Metalworking Prod.*, 1955, **99**, Nov. 4, 1872–1874). Four automated production lines for 8-mm and 10-mm bolts and nuts are in operation in a Russian agricultural machinery works at Taganrog. They comprise standard machines with transfer mechanism and have been designed by a department of the Ministry of Machine Tool Production.—M. A. K.

**Metal Spinning.** R. E. Baskerville. (*J. Junior Inst. Eng.*, 1955, **66**, Nov., 43–58).

**Metallurgical Control of Drop Forging.** K. J. Abbott. (*Eng. Insp.*, 1955, **19**, Spring, 23–32). The author deals with the production of steel drop forgings from the viewpoint of metallurgical and quality control. Grain flow, bar or billet material, material reception tests, heating and forging procedure, heat-treatment, and final mechanical testing are discussed.—P. M. C.

**Orientation of Crystal Structure in Galvanized Steel Wire after Drawing.** W. Gruhl and I. Eisenhuth. (*Stahl u. Eisen*, 1955, **75**, Aug. 25, 1100–1101). The Zn coating on galvanized wire shows no preferred orientation, but when the wire is reduced 30% by drawing, the coating shows a double conical

fibrous texture. As the degree of reduction is increased to 96%, the orientation changes to a single conical fibrous texture and the steel core is preferentially oriented with the [110] direction at right-angles to the length of the wire.—J. P.

**Precise Measurement of Wire Diameters. A New Apparatus.** I. G. Morgan. (*Instruments in Industry*, 1955, **2**, Oct., 225–226). An apparatus is described for the precise measurement of wire diameters to 0·25$\mu$ or better, applications being given to the absolute measurement of diameters and of variations in diameter along a length of wire.—L. D. H.

**A Study of Wire Drawing.** M. Velasco de Pando. (*Dyna*, 1955, **30**, Aug., 497–501). [In Spanish]. The author has applied his new theory of plasticity to wire drawing. The mathematical relationships are illustrated with reference to a mild steel wire of 4·4 mm dia. reduced to 3·7 mm dia.—P. S.

**The Promotion of Fluid Lubrication in Wire Drawing.** D. G. Christopherson and H. Naylor. (*Inst. Mech. Eng., Advance Copy*, 1955, Apr. 1, 2–12). It is suggested, on the basis of an experimental study, that true hydrodynamic (fluid film) lubrication with consequent reduced die wear can be realized in wire drawing by supplying oil to the die entry at a pressure comparable with the yield strength of the wire. It is shown that this necessary pressure can be conveniently generated by causing the wire to approach the die through a tube of diameter slightly larger than that of the wire, sealed to the inlet side of the die. A theory of the behaviour of the inlet tube and of temperature distribution in the system is also presented.—P. M. C.

**Thread and Form Rolling.** C. T. Appleton. (*Mech. Eng.*, 1955, **77**, Oct., 866–871). An outline is given of the thread-rolling process and its many advantages listed. The equipment used is described and the many applications of the process discussed.—D. H.

## ROLLING-MILL PRACTICE

**A Slip Line Field For The Hot Rolling Process.** J. M. Alexander. (*Inst. Mech. Eng., Advance Copy*, 1955, Sept. 19). By using a geometrical representation recently proposed by Prager, the author has obtained a solution to the statically undetermined problem of hot rolling. The geometrical method facilitates adjustment by inspection of the slip-line field until both velocity and stress-boundary conditions are satisfied. To allow for roll rotation it has been necessary to consider the effect of rotation on hodographs in detail. An interesting feature of the solution is the occurrence of a thin slice of rigid material adjacent to the roll surface at the entry point, having a large-velocity discontinuity along its boundary.—P. M. C.

**New Turkish [34-in.] Slabbing and Blooming Mill.** (*Metallurgia*, 1955, **52**, Aug., 62–63).

**Rational Grooving of Blooming Rolls.** S. A. Gurov and I. M. Konovalov. (*Stal*, 1955, (2), 181–183). [In Russian]. The extensive use and advantages of rhombic grooves in blooming rolls are described and the theory of such passes is briefly dealt with.—S. K.

**Rolling Mill Plant at the Works of Bochumer Verein: Electrical Twin Drive of Blooming Mill.** (*Iron Coal Trades Rev.*, 1955, **171**, Aug. 12, 383–385). Details are given of the design and operation of the blooming and billet mills at the Bochumer Verein works. A special feature of the blooming mill is its electrical twin-drive with rectifiers.—G. F.

**Effect of Certain Primary Mill Heating and Rolling Practices on Slab Surface Quality.** H. B. Wishart and C. A. Hope. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, July, 811–812). The authors summarize works' data showing the influence on slab surface quality of the amount of reduction from ingot to slab, slab finishing temperatures, and frequency of roll changes. Surface quality is evaluated by the proportion of surface removed by scarfing.—G. F.

**Electric Equipment for Cold Rolling Mills.** K. Döly. (*A.E.G. Progress*, 1955, (2), 60–65). The high demand for thin-gauge steel sheet has increased rolling speeds in cold-rolling mills. This has led to the development of highly perfected control systems for the electric drives.—B. G. B.

**The Electrical Equipment of the Tandem and Temper Pass Cold-Rolling Mill at Andernach.** B. Schoele. (*A.E.G. Progress*, 1955, (2), 65–73). This mill was put in operation in 1953 and was the first continuous cold-rolling mill in Germany. It is of the 5-stand tandem type but is currently operated with only 3 stands. When all 5 stands are in operation the maximum strip speed is 4100 ft/min. The electrical equipment for this mill is described in detail.—B. G. B.

**Rolled Flow Forming of Toothed Parts.** H. Pelphrey. (*Machine Shop Mag.*, 1955, **16**, July, 427–429). The article describes a cold-working process for the production of toothed parts by roll forming on the 'Roto Flo' machine.—M. A. K.

**Cold-formed Steel Sections: Manufacturing Processes.** E. Griffin and J. M. Harvey. (*Iron Steel*, 1955, **28**, Aug., 391–393). The authors discuss the four main groups into which the manufacturing process of cold-formed sections can be subdivided. They are rotary gang slitting, cold forming, assembly, and finishing.—G. F.

**Design and Ventilation of Large Direct Current Rolling-Mill Motors.** K. Bobek and F. Sprengel. (*A.E.G. Progress*, 1955, (2), 135–139). The demand for the shortest possible time of reversal for rolling-mill motors has led to the design of special motors having a low moment of inertia. These motors have a tendency to be compact but long. The problems encountered in the design and ventilation of these motors are discussed.

**Modern Electric Drives in a Semi Continuous Steel Bar, Strip and Rod Rolling Mill.** R. Zwicky. (*Brown Boveri Rev.*, 1954, **41**, Dec., 450–455). The main drives of a modern hot-rolling mill are described in which the rapid accurate regulation of one of the three groups of driving motors is of particular interest.—B. G. B.

**The Planetary Mill and Its Drive.** J. T. Jones. (*English Electric J.*, 1955, **14**, Sept., 24–28). The design of the electrical drive for a planetary mill designed for rolling alloy steels down to 0·040 in. from slabs $1\frac{1}{2}$–$1\frac{3}{4}$ in. thick and 15 in. wide is discussed.—B. G. B.

**Fairless Works—Electric Equipment for Slabbing Mill and Blooming Mill.** R. H. Wright and N. L. Kincaid. (*Trans. Amer. Inst. Elect. Eng.*, 1954, **73**, Part II, 141–144).

**Electrical Equipment for Rolling Mill Auxiliary Drives.** P. F. Renn. (*A.E.G. Progress*, 1955, (2), 74–79). The most important features of a.c. and d.c. rolling-mill auxiliary drives and of their controls are discussed and some suggestions are made concerning their economical and rational planning.

**Performance Calculations of Electric Motors for Roll Setting Drives.** L. Winter. (*A.E.G. Progress*, 1955, (2), 79–83). A graphical method is described for determining the duration of the accelerating and baking periods in terms of the reversal paths of rolling schedules. The method is illustrated by the calculation for a roll setting of a blooming and slabbing train.

**Ward–Leonard Control for Auxiliary Drives in Heavy Reversing Mill Trains.** H. E. Knoblock. (*A.E.G. Progress*, 1955, (2), 84–87). A number of important points which must be considered during the planning, construction, and operation of this type of control in rolling mills are described. Details are given of the drives for a 9·8-ft heavy plate mill and a 9·8-ft light plate mill.–B. G. B.

**Rectifier-fed Auxiliaries in Rolling Mills.** K. Jabs. (*A.E.G. Progress*, 1955, (2), 88–91). The development of suitable rectifier controls has made it possible to utilize the rapid acceleration, deceleration, and impulse control offered by rectifier operation. A rectifier-fed installation of auxiliaries in a heavy plate mill is described.—B. G. B.

**Steel Strip Cut-Up Line Solves Handling Problems.** P. M. Unterweiser. (*Iron Age*, 1955, **176**, July 21, 91–94). An unusual strip-preparation line at Dana Corp., Pa., is described. Hot-rolled steel strip is cleaned of scale, cut to size at a selected angle, phosphate-lubricated, and stacked ready for forming. Capacity is 50 tons/h.—D. L. C. P.

**Sorting Instrument for Transformer Sheet.** A. Winter and J. Gäbler. (*Technik*, 1955, **10**, July, 419–420). An instrument for the routine sorting of different grades of transformer sheet is described and illustrated. The instrument tests full-size sheets.—J. G. W.

## MACHINERY FOR IRON AND STEEL PLANT

**Automatic Control of Metallurgical Furnaces.** H. C. Dawson. (*Canad. Metals*, 1955, **18**, Aug., 20–25). A short account of the use of pneumatic and electronic controllers for the automatic regulation of furnaces is presented.—B. G. B.

**A.C. Power System at the Fairless Works.** S. S. Watkins, W. A. Derr, L. L. Fountain, and R. B. Squires. (*Trans. Amer. Inst. Elect. Eng.*, 1954, **73**, Part II, 343–352).

**Gas Turbines in the Iron and Steel Industry: Operation of Blowers and Electric Power Generators.** (*Iron Coal Trades Rev.*, 1955, **171**, Sept. 2, 563–566). The increasing use of gas turbines in the Continental iron and steel industry for power

generation and furnace blast is discussed, and factors influencing their choice are considered. Details are given of installations in Spain, Luxemburg, and Belgium.—G. F.

**Tonnage Oxygen Developments at Scunthorpe.** R. E. Doré. (*Iron Coal Trades Rev.*, 1955, **171**, Sept. 30, 792–793). The author discusses the proposed new tonnage oxygen plant to be erected by British Oxygen Co., Ltd., at Scunthorpe. The plant will supply and distribute oxygen to the local industry.

**A Lesson in Crane Safety.** (*Steel*, 1955, **136**, June 6, 88–90). Safety devices which may be installed in heavy steelworks cranes are considered, including limit switches, special ladle blocks, equalizer bars, safety ropes, load cells, duplicate motors, bumpers, and operator and maintenance staff protection.—D. L. C. P.

**Instrumentation in Steelworks.** G. Husson and M. P. Leroy. (*J. Iron Steel Inst.*, 1956, **183**, May, 54–63). [This issue].

**Instrumentation in the Making and Processing of Steel: Review of Current Practice and Prospects of Development.** S. S. Carlisle. (*Iron Coal Trades Rev.*, 1955, **170**, May 27, 1209–1217). The author reviews present-day instrumentation practice in the iron and steel industry, and discusses possible future developments. He deals firstly with process-measuring and control instruments connected with blast-furnaces, O.H. furnaces, gas producers, and rolling mills; and secondly, with gauging, inspection, and testing instruments used in the finishing processes.—G. F.

**Electromagnets for Lifting.** J. C. Griffiths. (*Elect. Rev.*, 1955, **157**, Sept. 2, 427–430). The article first describes the main functions of the principal types of lifting magnet—circular, rectangular, and bi-polar—discusses the question of magnet design, and finally mentions a few examples of magnets designed for special purposes.—L. D. H.

## WELDING AND FLAME-CUTTING

**Report of [I.I.W.] Commission 10: Residual Stresses and Stress Relieving.** R. Weck. (*Brit. Welding J.*, 1956, **3**, Jan., 19–21).

**Continuous-Cooling Transformation Diagram and Weldability of a 2½% Ni–Cr–Mo Steel.** B. J. Bradstreet. (*Brit. Welding J.*, 1956, **3**, Jan., 30–32). A continuous-cooling transformation diagram has been produced for a commercial 2½% Ni–Cr–Mo steel by simulating, as far as possible, the thermal conditions occurring in the heat-affected zones of metal-arc welds. Conditions have been established for producing crack-free welds in the steel, using low-hydrogen ferritic or austenitic electrodes.—U. E.

**Stress Studies of Various Shaped Welded Doubler in Hatch Corner.** H. Kihara, Y. Akita, N. Ando, and K. Yoshimoto. (*Welding J.*, 1955, **34**, Oct., 465s–471s). Nine large welded-ship hatch corner specimens containing welded doubler reinforcement of various shapes at the hatch corner were tested under tension. For all specimens the maximum stress concentration occurred in the deck plate at the periphery of the hatch corner.—U. E.

**Effect of Preheating on Stress-Corrosion Cracking of Steel Weldments.** E. P. Degarmo and I. Cornet. (*Welding J.*, 1955, **34**, Oct., 472s–475s). Three steels of 0·09–0·24% C, containing a 2-ft submerged-arc weld, were immersed in an aqueous solution of 60% $Ca(NO_3)_2$ and 3% $NH_4NO_3$ at 225–235° F in the as-welded, 400° F preheat, and high-temperature stress-relieved conditions. Such preheating was of considerable benefit, reducing stress-corrosion cracking in steel welds.

**Heat Treatment of Air Hardening Alloys on Welding.** J. J. B. Rutherford and J. F. Ewing. (*Welding J.*, 1955, **34**, Oct., 476s–483s). The influence of weld preheating temperature on hardness and microstructure of heat-treated welds of air-hardenable alloys was investigated. Excessive weld preheating temperature resulted in the presence of important quantities of hard untempered martensite in welds. The start of martensite transformation at 1300° F in 9% Cr, 1% Mo alloys could be speeded up by first subcooling to 1000–800° F and then reheating to 1300° F for transformation.—U. E.

**Welding Variables and Hardfacing Deposits.** A. Zvanut and V. Peters. (*Canad. Metals*, 1955, **18**, Aug., 56–58; Sept., 55–57). The types of hard coating available and their application by welding are considered. The cooling rate of the deposit has a great influence on the hardness and abrasion resistance. An austenitic structure has good abrasion resistance and the surface hardness increases by cold working. A martensitic structure has high hardness and abrasion resistance. A mixed bainite, cementite, and martensite structure has high hardness and low abrasion resistance.

**Mechanical Properties of Arc Welded High Strength Steel.** F. Bollenrath, H. Cornelius, and C. Appaly. (*Schweissen u. Schneiden*, 1955, **7**, Aug., 345–351). An investigation was carried out on arc welded Cr–V steel for determining the weldability and mechanical properties. Comparing the results obtained with arc welded plate of 12–20 mm thickness with those of flash-butt welded plate of the same thickness, it was found that the arc-welded samples showed a better bending angle and better fatigue properties.—U. E.

**Investigation on Mechanical-Technological Properties and Weldability of Low-alloy High-strength Structural Steels.** A. Fry, W. Hofmann, and F. Behrens. (*Schweissen u. Schneiden*, 1955, **7**, Aug., 341–345). A number of casts were made with a high P and S content and deoxidized with Ti. Samples, cut from different parts of the ingot, were welded and tested using the tensile, bend, and impact methods. High impact figures at low temperature were obtained for samples in normalized and aged condition. The weldability was found to be good provided no 'fish-eyes' are present. The tensile strength and toughness figures for the experimental steel were found to be similar to those of O.H. steel.—U. E.

**Static and Fatigue Strength of Fillet-Weld Connections. Between rolled angle sections and gusset plates.** F. Koenigsberger and H. W. Green. (*Brit. Welding J.*, 1955, **2**, Sept., 369–372). The fatigue-loading aspect of fillet-weld connections has been investigated and it has been found that whereas the proportioning of welds is in itself of no consequence, provided that sufficient throat area of weld exists, the position of the welds may influence the fatigue strength.—U. E.

**Modified Navy Tear Test for Measuring the Work of Fracture Propagation in Ductile Metals.** H. E. Romine. (*Welding J.*, 1955, **34**, Aug., 396s–408s). The original Kahn design of Navy tear test was modified by using Schmadt's roller-bearing principle to eliminate unwanted plastic deformation. Substantial differences were found in $dW/dA$ between longitudinal and transverse tear tests, regardless of heat-treatment. Annealing, and normalizing though improved transverse $dW/dA$ values.—U. E.

**Effect of Pretreatment of Martensite on Subsequent Graphitization at 1200° F.** G. V. Smith, E. J. Dulis, and B. W. Royle. (*Welding J.*, 1955, **34**, Aug., 374s–378s). A martensitic eutectoid steel was found to form many more nodules of graphite at 1200° F if first exposed in the range 800–1000° F, suggesting a possible relation between the high susceptibility of martensite to graphitization and the transition from $\epsilon$ carbide to cementite. The steel could be completely graphitized at 1200° F in 100 days, and showed an unusual reaction curve such that the rate slowed markedly after 5 days' exposure.—U. E.

**Tension-Impact Properties of Austenitic Stainless Steels at Ambient and Low Temperatures.** A. Choquet, V. N. Krivobok, and G. Welter. (*Welding J.*, 1955, **34**, Aug., 361s–373s). An investigation was conducted on stainless steels of commercial designation such as ¼ and ½ hard, and static and dynamic properties for base metal and butt-welded assemblies were determined. Results are given in tables and graphs.—U. E.

**Welding Chromium Steels.** L. E. Fedotov. (*Avtog. Delo*, 1953, (6), 20–21). [In Russian]. The special features of the welding of Cr steels are considered with special reference to their Cr contents. The welding of low-carbon steels to Cr steels is discussed and the necessity of using austenitic Cr–Ni electrodes for most conditions is discounted.—S. K.

**Welding of Chrome-Moly Steels in High-Pressure High-Temperature Service.** C. D. Cooper. (*Welding J.*, 1955, **34**, Sept., 882–884).

## LUBRICATION

**Deformation Properties of Friction Junctions.** J. A. Greenwood and D. Tabor. (*Proc. Phys. Soc.*, **B**, 1955, **68**, Sept. 1, 609–619). The mechanism of sliding friction is investigated, by shearing models of friction junctions, for cases of very strong and weak adhesion and lubricated sliding; results agree with theoretical solutions from plasticity theory.—K. E. J.

**New Industrial Applications of Molybdenum Disulphide.** H. P. Jost. (*Mech. World*, 1955, **135**, Nov., 489–491). Brief details are given of the use of molybdenum disulphide as a lubricant under conditions of high temperature and pressure. Correct particle size and purity are vital factors in its application.—D. H.

**Evaluation of Greases for Ball- and Roller-Bearings at Low Temperatures.** J. W. Pearson. (*J. Inst. Petroleum*, 1955, **41**, Sept., 290–296). An apparatus is described which may be used for measurements at constant shear stress or constant rate of shear on grease in bearings at low temperatures.

**Lubricating Properties of Pure Molybdenum Disulphide.** A. Sonntag. (*Maschinenwelt Elektrotechnik*, 1955, **10**, July, 182–183; Sept., 225). The lubricating properties of pure molybdenum disulphide are outlined, and its application is described to severe or unusual conditions where substantial improvement is to be expected from its use.—L. D. H.

## MACHINING AND MACHINABILITY

**Cutter Design and Application for Face-Milling Cast Iron and Steel.** O. W. Boston and W. W. Gilbert. (*Trans. Amer. Soc. Mech. Eng.*, 1955, **77**, Oct., 1123–1131). The paper records the results of tests to face-mill cast iron and steel with cutters of various materials, sizes, and shapes.—D. H.

**Copy-turning Large Pipe Moulds.** (*Machinery*, 1955, **87**, Oct. 7, 849–850). The profile turning of moulds made from Ni–Cr–Mo steel forgings and weighing up to 15 tons is described. The machining is carried out at the River Don works of English Steel Corporation Ltd.—M. A. K.

**Pneumatic Apparatus for Measuring the Flatness of Plates.** J. C. Evans and I. G. Morgan. (*Machine Shop Mag.*, 1955, **16**, Oct., 601–603). The equipment works at a pressure of about 5 lb/in$^2$; errors of flatness are shown directly by the levels of columns of coloured water in parallel manometer tubes. A magnification of approximately 2500 is obtained and operates over a linear range of $\pm$ 15$\mu$. Linearity is to within 1%. The principles involved can be applied also to the checking of straightness; a further model for checking the straightness of cylindrical rods is under construction.

**Machinability of Aircraft Steel D.T.D. 331 (BS 99) Using H.S.S. Tools.** J. Cherry. (*Machine Shop Mag.*, 1955, **16**, Sept., 549–556). The article discusses investigations carried out on a Ni–Cr steel of 80–90 tons tensile strength to Ministry of Aircraft Production Specification D.T.D. 331 (B.S. 99). Basic tests to determine tool shape and tool life were conducted on a centre lathe, followed by comparative tests on cylindrical milling to test their validity for this operation.—M. A. K.

**Fundamentals of Surface Finish.** H. Selinger. (*Australian Machinery Prod. Eng.*, 1955, **8**, Mar., 5, 7, 9, 11, 13, 14, 40; Apr., 5, 7, 9, 11, 13). The author deals first with the measurement of surface irregularities by stylus instruments, and then discusses in detail the different methods of numerical assessment. Both British (BS 1134) and foreign measuring practices are discussed, notably the C.L.A. (average above centre-line) and R.M.S. (root-mean-square) methods. The second part deals with practical problems and applications of surface finish measurement, including interference shrink fitting, fatigue, corrosion, frictional wear, and machining.—P. M. C.

**French Methods and Apparatus for Measuring Surface Finish.** A. Mirau. (*Rev. Univ. Min.*, 1955, 9th series, **11**, Sept., 461–469).

**The Historical Development of Free Cutting Steels.** G. B. Morrison. (*Proc. Staff. Iron Steel Inst.*, 1946–53, **61**, 11–29).

**Contribution to Research into the Cutting Process.** Th. Stroppel. (*Z.V.d.I*, 1955, **97**, Aug. 21, 829–830). The fundamental mechanics of cutting and shearing by knife-like tools are briefly discussed. Reference is made to a replica technique for the measurement of the cutting profile of razor blades.

## CLEANING AND PICKLING

**Dust Control at Foundry Knock-Outs.** W. D. Bamford. (*Brit. C.I. Res. Assoc., J. Res. Dev.*, 1955, **6**, Oct., 38–55). The design of knock-out ventilating systems is discussed and methods of providing effective control of dust- and fume-bearing air currents with the minimum volume of exhaust air are explained. A method of preventing the raising of dust from moulding sand after knock-out is indicated.—B. G. B.

**The Use of Commercial Inhibitors.** (*Inst. Vitreous Enamellers' Bull.*, 1955, **6**, Nov., 57–68). The final report is presented of a committee which investigated the use of inhibitors in acid pickling in the preparation of sheet steel for enamelling. Replies to a questionnaire are summarized and it is concluded that inhibitors have no detrimental effect on adhesion or quality of enamel and reduce metal loss during pickling.

**Barrel Finishing.** (*Metal Ind.*, 1955, **86**, May 20, 419–421). The general principles and uses of barrel finishing are described. Four main groups of processes—rough tumbling, grinding, deburring, and burnishing—are all classed as barrel finishing. The equipment, tumbling media, and operational details are outlined.—P. M. C.

**The Installation of Degreasing Plant.** G. Miel. (*Usine Nouvelle*, 1955, **11**, Dec. 15, 35–38). Suggestions are made for the correct installation of degreasing apparatus and associated equipment with a view to avoiding health hazards and obtaining maximum safety and working comfort. Particular reference is made to the use of the chlorinated derivatives of ethylene.—T. E. D.

**Shot for Peening.** M. Uchiyama and K. Kamishohara. (*Tetsu to Hagane*, 1955, **41**, Aug., 857–861). [In Japanese]. The life of shot, as influencing the quality of the shot mixture, was investigated, using ferrous and non-ferrous shot in a specially designed test machine. Large, hard, and faster-travelling shot had low lives, but gave high peening intensities. For the same intensity, the lives of ferrous shots were in the order cut steel wire > cast steel > cast iron.—K. E. J.

**Modern Ferrous and Non-Ferrous Pickling Speeded with Cast Corrosion Resistant Alloys.** (*Indust. Heating*, 1955, **22**, Sept., 1796–1806, 1876). Examples are given of the application of cast alloys containing 18–21% Cr, 8–31% Ni, and 2–3% Mo in pumps and other parts for pickling plant. Equipment for pickling stainless steel and silicon iron is briefly described.—A. D. H.

**Contract Electropolishing.** (*Electroplating*, 1955, **8**, June, 220–222, 226). A description of plant and processes for electroplating 18/8 stainless and 17% Cr steels at the Brightside Electropolishing Co., Ltd., Birmingham.—A. D. H.

**Electromachining and Superfinishing as a Production Tool. II.** A. T. Steer. (*Electroplating*, 1955, **8**, July, 245–249). The requirements of finishes for highly stressed aircraft parts are discussed. The beneficial effect of vapour blasting after electro-polishing on the fatigue behaviour is demonstrated by reference to several examples.—A. D. H.

**Progress in Barrel Finishing. I. The Development and Technique of Barrel Finishing.** C. J. A. Kellard. (*Electroplating*, 1955, **8**, Mar., 95–98; Apr., 149–152). The choice of abrasive (media) and operating variables are discussed. A bibliography of British Patents on barrel finishing covering the years 1879–1915 is included.—A. D. H.

**Corrosion Resistant Alloys Play Key Part in Pickling.** (*Iron Age*, 1955, **176**, July 7, 94–96).

## PROTECTIVE COATINGS

**Flame Plating Clads for Better Wear Resistance.** (*Iron Age*, 1955, **176**, Oct. 27, 88–89). Flame plating with tungsten carbide by the process described gives a tough wear resistant surface suitable for tools, gauges, and bearing surfaces.

**Modern Electroplating Plant.** W. H. Simons. (*Metal Ind.*, 1955, **86**, Apr. 29, 333–338). Trends in modern electroplating and anodizing plant and equipment are described, and typical installations illustrated. Materials of construction, heating methods, and polishing and degreasing techniques are discussed, and the design of plant for automatic plating is described.—P. M. C.

**Instrumentation in Electroplating.** J. L. M. Fletcher. (*Metal Ind.*, 1955, **86**, June 24, 533–537). A brief classification and description of the important types of instrument used in the plating shop is presented. Process control instruments for temperature, current supply, *p*H control, and the ' Hull cell ' are dealt with, together with quality-control instruments for determining deposit thickness, porosity, hardness, adhesion, and internal stress.—P. M. C.

**Plating Metal Powder Compacts.** C. C. Cohn. (*Metal Ind.*, 1955, **87**, Aug. 12, 128–129, 134). The factors which hinder successful electrodeposition of coatings on metal-powder compacts are discussed. The main hindrance is porosity. Plating can, however, be accomplished if the pores are first sealed by impregnation, using special resins, silicates, etc.

**Automatic Rinsing Control.** J. B. Mohler. (*Metal Ind.*, 1955, **87**, Oct. 21, 343–346). The mathematical approach to problems of single, multiple, and spray rinsing of articles lifted from plating tanks is described. Rinsing efficiency can be expressed mathematically, and rinse concentrations can be predicted where the drag-in is known. Automatic control of rinsing operations is discussed.—P. M. C.

**Electrodeposition.** A. E. Davies. (*Soc. Chem. Ind., Reports on Progress of Appl. Chem.*, 1954, **39**, 117–128). The most important work has been the study of levelling power and the

action of organic brightening agents. Sulphamate solutions have been introduced for the production of stress-free Ni deposits. Iron may be electrodeposited from an alkaline solution of ferric iron, triethanolamine, and E.D.T.A. A cathode efficiency of 75% may be attained but anodic replenishment is not possible.—E. E. W.

**Developments in Bimetallic Construction.** (*Mech. World*, 1955, **135**, Sept., 414–415). Intermolecular bonding of Al to steel and Ti permits adjustment of strength/weight ratio, cost, wear, and corrosion resistance of machine parts. Bonding is achieved by a tinning and casting process widely adaptable to different design requirements.—D. H.

**Testing the Thickness and Adhesion of Electroplated Coatings.** (*Mech. World*, 1955, 135, June, 256–261). The paper discusses briefly various plate thickness and adhesion tests, particularly the B.N.F. jet test for thickness measurement.

***p*H for the Electroplater.** J. B. Mohler. (*Products Finishing*, 1955, **19**, July, 32–42). An elementary account of the influence and measurement of pH in plating operations.—A. D. H.

**Rinse Tank Control.** J. B. Mohler. (*Metal Finishing*, 1955, **53**, Sept., 66–68). The application of conductivity controllers to control the operation of rinse tanks in electroplating is discussed.—A. D. H.

**Plating Bath Control: Past, Present and Future.** J. B. Kushner. (*Metal Finishing*, 1955, **53**, May, 59–63).

**Do's and Dont's in Plating Operations.** C. Buelfman. (*Metal Finishing*, 1955, **53**, Apr., 40–47, 55). The application of ion-exchange resins to the purification of plating effluents containing Cr is discussed.—A. D. H.

**Simplified Experimental Study of the Electrochemical Behaviour of a Metal. The Particular Case of Ferrosilicon in Alkaline Solution.** J. Besson and M. Mathé. (*J. Chim. Phys.*, 1955, **52**, June, 473–478). A simple method of following the polarization curves of a metal is described. It is applied to a range of ferro-silicons (5–90% Si) in KOH solution, in view of their possible use as inert anodes.—T. E. D.

**Materials Testing in Electro-plating.** J. Elze. (*Metall*, 1955, **9**, June, 458–465). Tests of the mechanical, physical, chemical, and electrochemical properties of coatings used in the electroplating industry are surveyed. Data on properties obtained by various treatments are quoted.—J. G. W.

**New Chrome Plating Process Deposits Highly Ductile Coatings.** P. J. Topelian. (*Iron Age*, 1955, **176**, Oct. 13, 99–101). Properties and applications of Cr plating applied to a variety of base metals by processes developed by Tiarco Corp., N.J., are described. Hard, dense, ductile coatings with good adherence are possible on Al, Ti, cold-rolled steel, and other metals.—D. L. C. P.

**Crack-Free Chromium: Process for Direct Plating on Steel.** (*Metal Ind.*, 1955, **87**, Sept. 9, 223–224). Ordinary Cr plate contains pores or, if above 0·0001 in. thick, cracks which allow corrosive agents to reach the underlying metal. A new process has now been developed by United Chromium Inc., U.S.A., which deposits a crack-free deposit from a special chromic acid type bath having automatic regulation of the catalyst concentration. Excellent properties and corrosion resistance are claimed.—P. M. C.

**The Electropolishing of Chromium and its Alloys.** K. F. Lorking. (*Bull. Inst. Met. Finishing*, 1955, **5**, Summer, 119–126).

**Properties and Uses of Heavy Nickel Deposits.** J. W. Oswald. (*Electroplating*, 1955, **8**, Nov., 379–383). Solutions for the deposition of Ni are given. Properties and applications of the process are presented and Ni plating is compared with hard Cr plating.—A. D. H.

**The Prevention of Cracking in Nickel Deposits.** C. F. Gurnham. (*Products Finishing*, 1955, **19**, July, 62–68). [A summary of a paper by T. E. Such, *Inst. Metal Finishing*, 1955].

**Bright Nickel Plating Solutions.** T. E. Such. (*Electroplating*, 1955, **8**, Sept., 308–315; Oct., 347–350). The types of bright and semi-bright Ni plating processes are described and their relative advantages are discussed. Control systems, including the use of a Hull cell for checking the appearance of the deposit and methods of bath purification with activated carbon and high pH treatments, are also dealt with. Descriptions are given of the plant used and practical aspects of working the process and of testing plated articles are discussed.—A. D. H.

**Recent Developments in the Electrodeposition of Nickel and Chromium.** E. A. Ollard. (*Indust. Finishing*, 1955, **8**, Mar., 152–156). The review includes a discussion of the introduction of bright Ni baths and of new solutions for the deposition of Cr.—A. D. H.

**Zinc Coatings on Steel.** R. W. Bailey. (*Indust. Finishing*, 1955, **8**, July, 401–409). The history and characteristics of hot-dip, electrodeposited, sprayed, Sherardized, and painted Zn coatings are described.—A. D. H.

**Galvanizing Cast Iron.** W. Montgomery. (*Tecn. Indust.*, 1955, **33**, July, 881–882). [In Spanish]. The structure of cast irons and the influence of the microconstituents upon the galvanizing process are described. Methods employed in the surface preparation of castings before galvanizing are discussed.—P. S.

**Manufacture and Thermal Treatment of Zinc Coating.** W. Katz. (*Metall*, 1955, **9**, Aug., 652–655). Composition and structure are surveyed and the suitability of the particular test for various uses are discussed.—J. G. W.

**'Quenching' of Hot-dip Galvanized Products.** H. Bablik, F. Götzl, and E. Nell. (*Metall*, 1955, **9**, Aug., 643–645). Various quenching and slow cooling treatments after hot-dip galvanizing are discussed from the point of view of their effect on composition, structure, and properties of the coating.—J. G. W.

**Tinned Steel Strip Manufacture.** G. P. Zwanefeld. (*Metalen*, 1955, **10**, July 15, 276–280). [In Dutch]. The article describes briefly the various processes connected with the production of tinned steel strip at the plant run by the Breedband N.V. at Ymuiden, Holland.—F. R. H.

**Copper Plating from Pyrophosphate Baths.** T. A. Dickinson. (*Metal Finishing J.*, 1955, **1**, Aug., 343–345). A description of practice for electrodeposition of Cu from pyrophosphate baths. The solutions are non-toxic, non-corrosive, and produce smooth coatings. Compositions of solutions are given.—A. D. H.

**The Heat Resistance and Applications of Hot Dip Aluminized Steel.** M. L. Hughes and D. F. G. Thomas. (*Metallurgia*, 1955, **52**, Nov., 241–245). Tests show that the scaling resistance is very good and somewhat better than with Al–Si coatings. Tests on the influence of $SO_2$ in the atmosphere show that there is little effect below 800° C. The applications of hot-dipped aluminized steel are discussed.—B. G. B.

**New Clad Metals Made by Vacuum Brazing.** K. Rose. (*Mat. Methods*, 1955, **42**, July, 100–102). The 'Hortonclad' process developed by the Chicago Bridge and Iron Co. is described. The two metals to be joined are placed in a furnace with a thin foil of brazing alloy between them. As the brazing alloy melts, a vacuum of 29–30 in. of mercury is drawn between the plates, which are thus forced together by atmospheric pressure. Thinner alloy layers, new combinations of metals, and better surface finishes are claimed for the new process. Forming characteristics and mechanical properties of the composite sheets are reported to be very satisfactory.—P. M. C.

**Bronze Plating: Why and How.** F. A. Lowenheim. (*Metal Finishing*, 1955, **53**, July, 51–52, 58). The use of the potassium-stannate–copper-cyanide bath for the deposition of 10% Sn bronze is described and discussed.—A. D. H.

**The Protection of Iron and Steel by Sprayed Coatings of Aluminium and Zinc.** F. A. Champion. (*Electroplating*, 1955, **8**, May, 180–182, 189). The characteristics of sprayed Zn and Al coatings on steel at ordinary and elevated temperatures are discussed in relation to the recent B.S. Specification 2569.—A. D. H.

**Some Aspects of the Hardfacing Process.** L. J. Lalor. (*Engineer Foundryman*, 1955, **20**, June, 42–48). The characteristics of Fe-, Ni-, and Co-based alloys and of tungsten carbide for hard-facing are discussed and methods of their application to mild steel are described. Hardness testing is explained.—A. D. H.

**Plated or Clad Metals.** (*Usine Nouvelle*, 1955, **11**, Aug. 25, 57–61). Coating of metals by plating or cladding with a different metal is discussed, and the use of organic coatings is mentioned. A comprehensive table is given showing the method of fabrication, thickness, performance, and applications for various coatings on a number of metals and alloys.

**Metallizing.** S. M. Checa Casajus. (*Inst. Hierro Acero*, 1955, **8**, July-Sept., 374–383). [In Spanish]. A review of the process is given; equipment and methods are described. Surface preparation for, and the quality and requirements of, metal coatings are discussed and typical applications are given.—P. S.

**The Importance of Metal Spraying for Maintenance Work**

**in Iron and Steelworks.** J. Wingerath and F. W. Griese. (*Stahl u. Eisen*, 1955, **75**, Sept. 8, 1189–1197). The field of application of metal spraying in repair work in iron and steelplants is reviewed. The examples show that its possibilities are many and that it ought to be used more widely. Metal spraying offers not only a saving of cost but also makes possible repeated repairs, and, because of its rapidity, reduces downtime. Moreover, metal spraying gives surfaces which, for many purposes, are better for operational requirements. Introduction of metal spraying requires, however, that the working conditions and the limitations of the method should be rigorously observed, otherwise the whole process is discredited and further application made difficult.—J. P.

**Mould Spraying.** H. J. Plaster. (*Electroplating*, 1955, **8**, Oct., 354–358). The manufacture of dies for plastics moulding by spraying steel on to a master pattern is described. The die can be hard Cr plated.—A. D. H.

**Metal Spraying and its Applications.** W. E. Ballard. (*Indust. Finishing*, 1955, **9**, Aug., 26–30). The history and uses of sprayed Al and Zn coatings are given.—A. D. H.

**Process Control of Cast Iron for Vitreous Enamelling.** J. Bernstein. (*Proc. Inst. Vitreous Enamellers*, 1952–53, 1953–54, **11**, 21–32). Foundry practice for the production of castings for wet process enamelling is described, and methods of applying acid-resisting enamels are outlined.—A. D. H.

**Some Aspects of the Manufacture of Sheet for the Vitreous Enamelling Industry.** E. Marks. (*Proc. Inst. Vitreous Enamellers*, 1952–53, 1953–54, **11**, 33–42, 52). Bessemer and O.H. steels are compared, and it is suggested that Bessemer steel rolled on a continuous wide-strip mill is especially suitable for vitreous enamelling.—A. D. H.

**Flow Production in Vitreous Enamelling.** A. R. Parkes. (*Metal Finishing J.*, 1955, **1**, Aug., 357–362, 368). A new vitreous enamelling plant at the Revo Enamel Co., Tipton, Staffs., is described in detail.—A. D. H.

**Mechanism of Blister Formation in Cast Iron Vitreous Enamels.** E. R. Evans. (*Product Finishing*, 1955, **8**, Oct., 67–78). Theories of blistering are reviewed with reference to defects encountered in practice. Preliminary experiments to study gas evolution from cast iron are described.—A. D. H.

**Protection of Structural Steel—The Preservation of Steel on Gas Works (Great Britain).** L. A. Ravald. (*Chem. Indust.*, 1955, Nov. 26, 1526–1535). The author surveys methods used in the gas industry for the pre-treatment of steel and describes various protective systems including the use of paints and metal coatings. Several special problems are discussed.

**The Protection of Structural Steel—Current Good Painting Practice for Steel Structures in the United States.** J. Bigos. (*Chem. Indust.*, 1955, Nov. 19, 1503–1510). Two volumes of a 'Steel Structures Painting Manual' have been produced in the U.S.A. by the Steel Structures Painting Council. The author, who is Director of Research of the Council, briefly reviews the factors of importance to corrosion of steel structures and discusses their application to protective schemes for typical structures.—E. E. W.

**Rambler Body Finishing at Nash Plant.** (*Indust. Heating*, 1955, **22**, June, 1235–1248, 1309–1318). The automatic plant used at the American Motors Corp., Wis., for body painting is described in detail.—A. D. H.

## POWDER METALLURGY

**A Method of Preparing Iron Powder for Permanent Magnets.** E. H. Carman. (*Metallurgia*, 1955, **52**, Oct., 165–168). An apparatus is described for the reduction by $H_2$ of small quantities of powdered iron oxide. The smallest iron particle size obtainable by the method is that of the oxide particles employed.—B. G. B.

**Adding Copper to Iron Powder Compacts.** P. U. Gummeson and L. Forss. (*Precision Met. Mold.*, 1955, **13**, Oct., 55–57, 92). The authors discuss the effects produced on the dimensions and properties of Fe powder compacts on the addition of Cu powder.—D. H.

**Powder Metallurgy.** T. Raine. (*J. B'ham. Met. Soc.*, 1954, Golden Jubilee Issue, 209–238). The principles involved in modern powder metallurgy, and the reasons for its adoption as a useful production method are reviewed. Detailed descriptions are then presented of the processes used for the production of refractory metals (W, Mo, and Ta), for hard metals (tungsten carbide, cobalt), and for sintered iron and steel. The production of the base material powders, and the properties of the products are also given.—P. M. C.

**Physical Investigation Methods Used in Powder Metallurgy—Their Application in Quality Control.** M. R. Bernard. (*Met. Ital.*, 1955, **47**, Aug., 367–376). [In French]. The author reviews the main problems associated with powder metallurgy and describes the various methods available for overcoming these. Details are given of modern control methods based on optical metallography, electronic microscopy, the measurement of specific surfaces, X-ray diffraction, magnetic measurements, electron diffraction, and radioactive tracers.—M. D. J. B.

**European Trends in Powder Metallurgy. II. Tooling to Produce Precision.** S. I. Hulthén. (*Metalworking Prod.*, 1955, 99, Sept. 23, 1643–1649). Special tooling provides a practical alternative to specially designed presses in some European powder-metal shops.—M. A. K.

**Dimensional Changes in Iron–Copper Sinter Alloys.** E. Pelzel. (*Metall*, 1955, **9**, July, 565–569). Various causes of dimensional changes in sintered Fe–Cu alloys are examined and tests with additives designed to counteract these are reported. Their effect on the mechanical properties is not left unconsidered.—G. W.

**Iron Powder by Electro-deposition.** S. Ranganathan and B. R. Nijhawan. (*J. Sci. Indust. Res.*, 1955, **14A**, July, 333–334). The authors describe the conditions required for obtaining particular deposits of iron from plating baths and give the results of their own experimental work.—E. E. W.

## PROPERTIES AND TESTS

**Quality Control Instrumentation.** C. M. Gilmour. (*Metal Ind.*, 1955, **86**, June 24, 529–532). A brief account is given of the applications of radioactive isotopes and ultrasonics to the measurement and control of strip and tube wall thickness, and internal flow detection.—P. M. C.

**Recent Investigations of the Mechanics of Cavitation and Cavitation Damage.** R. T. Knapp. (*Trans. Amer. Soc. Mech. Eng.*, 1955, **77**, Oct., 1045–1064). The author describes water-tunnel investigations into the mechanics of fixed-type cavitation and into the probable mechanism through which it causes material damage. All tests were carried out on pure annealed Al.—D. H.

**Testing, Inspection and Quality Control.** D. M. McCutcheon. (*Metal Progress*, 1955, **68**, Sept., 141–143). Developments in this field in the last 25 years are reviewed. The use of non-destructive techniques and of statistical quality control are explained.—B. G. B.

**Dislocations, Work Hardening and Creep.** N. F. Mott. (*Nature*, 1955, **175**, Feb. 26, 365–367). An outline is given of the present state of the theory of work hardening, and some new ideas on recovery and creep are proposed.—B. G. B.

**Considerations of Previous Work on Specifications.** J. Bernard. (*Métaux–Corrosion–Indust.*, 1955, **30**, Sept., 347–356). The problem of devising suitable specifications for steels for particular uses is discussed in detail.—B. G. B.

**The Inspection and Testing of Metals.** (*Inst. Metallurgists*, 1954). At the Institution's eighth Refresher Course, held in October, 1954, the following five lectures were delivered:

**The Inspection of Metals in Service.** G. A. Cottell. (3–31). The causes of failure are defined and discussed in detail. Typical examples of service failure and the testing techniques applicable to various materials and components are described.

**Inspection in the Steel Industry.** J. F. Hinsley. (32–50). Inspection is discussed in terms of (*a*) quality, (*b*) dimensions, and (*c*) specifications in relation to the more important processes in a typical steelworks.

**Inspection of Non-Ferrous Metals.** S. S. Smith. (51–79). The test procedures ancillary to production, and inspection against customer requirements and specifications are dealt with broadly.

**The Assessments of Methods of Destructive and Non-destructive Testing.** H. Harris. (80–89). The applications and limitations of tensile, fatigue, creep, and corrosion tests, of analysis and of radiographic, ultrasonic, and metallographic examinations are outlined.

**Batch Testing and Sampling of Metals.** H. J. Curnow. (90–119). Inspection and testing requirements are analysed and some methods of securing improved efficiency with overall economy are indicated.—L. E. W.

**Magnetic Fluid for Crack Detection.** V. Cadambe and K. C. Srivastava. (*J. Sci. Indust. Res.*, 1955, **14A**, May, 249).

**Results of Damping Capacity Measurements in the Investigation of Iron.** W. Köster. (*Inst. Hierro Acero*, Special Number, 1955, **8**, Oct., 520–540). [In Spanish]. It is shown how the measurement of the damping capacity of iron containing carbon and/or nitrogen in various conditions has provided important practical and theoretical data.—P. S.

**Non-deforming Steels.** J. Apraiz. (*Dyna*, 1955, **30**, Aug., 520–531). [In Spanish]. A review of the properties of the 1–3% Mn–5% Cr, and 12% Cr non-deforming steels is given. Methods of forging and heat-treatment are discussed, and special attention is given to the effects of heat-treatment and microstructure upon properties. Criteria for the choice of steel in relation to its service are also given.—P. S.

**Metal-physical Aspects of Steel.** E. Rudberg. (*Jernkontorets Ann.*, 1955, **139**, (9), 583–616). [In Swedish]. The main concepts and working theories of plastic behaviour are discussed and suggestions made as to their possible bearing on steel problems. Sections deal with slip as produced by moving dislocations, chief types of dislocations, the generation of new dislocations and their mutual interaction, application of dislocation theory to the phenomena of hardening and hardness, and the use of dislocation models of sub-grain boundaries.—G. G. K.

**Plastic Deformation and the Formation of Cracks by Detonating Charges.** C. H. Johansson. (*IVA*, 1955, **26**, (1), 16–25). [In English]. The maximum pressure of detonating TNT charges (1500 kg/m³) in the contact surface of steel was calculated as about 280,000 atm. Details are given of the plastic deformation occurring, elastic stresses and cracks due to the outgoing shock wave, speed of crack growth, and nature of fractures due to reflected shock waves.—G. G. K.

**Plastic Working of Metals.** F. Mazzoleni. (*Ing. Mecc.*, 1955, **4**, Aug., 17–24). [In Italian]. The author discusses cohesion in metals, plastic slip, the hot and cold working of metals, anisotropy after plastic deformation, oriented magnetic sheets, and the phenomenon of recrystallization. The plastic theory and work of deformation are also considered.—M. D. J. B.

**A Uniaxial Strain Model for a Lüder's Band.** E. W. Hart. (*Acta Met.*, 1955, **3**, Mar., 146–149). An expression is derived for the velocity of propagation of Lüder's lines in terms of the intrinsic stress/strain properties of the material.—A. D. H.

**Methods for Determining the Strength of Wire Cables.** K. V. Kovalev and N. I. Plyuksne. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 84–88). [In Russian]. Methods for testing cables under tension, bending and torsion are described. Examples of results for various types of cable are given.—S. K.

**A Study of Ductility and Tensile Strength of Gray Cast Iron.** A. Collaud. (*Roll'schen Eisenwerke, Mitt.*, 1954, **13**, July-Dec., 25–74). The relationship between the structure of grey cast iron and its tensile strength and ductility is investigated. It is shown that at breaking load the plastic deflection depends directly on the modulus of elasticity and increases when the notch effect of the lamellar graphite lessens. On the other hand, the plastic deflection is influenced by the ductility of the matrix and is inversely proportional to the Brinell hardness. The ductility is therefore proportional to its tensile strength and inversely proportional to the square of its Brinell hardness. It is found that an increase in ductility and toughness is of greater value than an increase in tensile strength.—U. E.

**The Mechanical Properties of Carbon Steel Wire at Low Temperatures.** R. W. Nichols. (*J. Iron Steel Inst.*, 1956, **182**, April, 337–347).

**Stress/strain Curves of Some Metals and Alloys at Low Temperatures and High Rates of Strain.** H. G. Baron. (*J. Iron Steel Inst.*, 1956, **182**, April, 354–365).

**Comparison of Slow Notch-Bend Test and V-Notch Charpy Impact Test. For the Assessment of the Notch Ductility of C–Mn Steel.** (*Welding J.*, 1955, **34**, July, 338s–346s). International Institute of Welding Report. Data are given of results obtained with **V**-notch Charpy specimens and slow notch-bend specimens of C–Mn steel. The two tests employed generally give a similar rating to the samples of 1-in. thick C–Mn plate.—U. E.

**Why the Izod Value ?** H. E. Davies. (*Proc. Staff. Iron Steel Inst.*, 1946–53, **61**, 61–77). A comprehensive account of the Izod test is presented. The author considers in some detail published results in an attempt to assess the true value of the test and its significance in predicting the behaviour of metals under service conditions.—B. G. B.

**Residual Lattice Strains in Sectioned Bars of Plastically Deformed Iron.** C. J. Newton and H. C. Vacher. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Nov., Sect. 1, 1193–1194). Results are given of an X-ray examination of residual stresses in sections of plastically deformed bars of ingot iron. They appear to be in line with the suggestion that the harder part of the two-part system is the highly distorted material at or near crystal boundaries, rather than an adjacent crystal of different orientation.—G. F.

**Polyaxial Stress–Strain Relations of a Strain-Hardening Metal.** S. B. Batdorf and B. Budiansky. (*J. Appl. Mech.*, 1954, **21**, Dec., 323–326). The authors assess a plastic stress/strain law of anisotropic strain-hardening type which they previously developed on the basis of explicit consideration of the polycrystalline nature of metals and the mechanism of plastic deformation. The assumptions made are reviewed, together with the successes and limitations of the theory.

**Residual Stresses in Cold Finished Steel Bars.** E. S. Nachtman. (*Mech. Eng.*, 1955, **77**, Oct., 836–889). The author discusses briefly the introduction of residual stress into cold-drawn bar by each of the treatments (i) cold drawing, (ii) turning, grading, and polishing, (iii) heat-treatment. The effect of residual stress on the properties of parts fabricated from cold-drawn stock is given.—D. H.

**Residual Grinding Stresses in Hardened Steel.** H. R. Letner. (*Trans. Amer. Soc. Mech. Eng.*, 1955, **77**, Oct., 1089–1098). Residual stresses resulting from surface grinding a hardened ball-bearing steel were measured by the deflection method and the effects of wheel grade, unit down feed, and grinding fluid upon the stresses generated were studied. The stress gradients close to the surface were quite steep and, in some cases, both components of the biaxial stress were compressive at the surface.—D. H.

**The Determination of Residual Stresses in Hardened, Ground Steel.** L. V. Colwell, M. J. Sinnott, and J. C. Tobin. (*Trans. Amer. Soc. Mech. Eng.*, 1955, **77**, Oct., 1099–1105). The residual surface stresses induced by grinding a hardened SAE 4340 steel have been investigated by means of X-ray diffraction and by optical interferometric methods. The depth of penetration of residual stresses increased with the severity of grinding, and the higher the hardness of the steel the higher their absolute value. The magnitude of the residual stresses varied between 100,000 lb/in² in tension to 135,000 lb/in² in compression. Light grinding produced residual compressive stresses whilst heavy grinding produced tensile stresses.—D. H.

**Practical Design Aspects of Fatigue Limits.** (*Mech. World*, 1955, **135**, July, 294–297). The characteristics of $S/N$ curves for various ferrous and non-ferrous metals are described and it is suggested that the latter, in certain cases, show a fatigue limit. The application of $S/N$ curves to design problems is discussed and the factors effecting their determination mentioned.—D. H.

**Mechanical Factors in the Fatigue of Steel Rock Drill Rods.** D. S. Kemsley. (*Proc. Australasian Inst. Min. Met.*, 1955, Sept., 21–34). A method is presented for calculating the number of stress cycles to failure of a drill rod from operating variables. The author concludes that the failure of rock drill rods by fatigue at the shank end is due to metallurgical corrosion fatigue rather than a purely mechanical stress distribution.—B. G. B.

**The Failure of Steel Rock Drill Rods by Fatigue.** D. S. Kemsley. (*Proc. Australasian Inst. Min. Met.*, 1955, Sept., 1–19). 50 fractured low Cr–Mo alloy drill steel rods of a type in common use in Australia were investigated. Causes of the failures are discussed and methods suggested for reducing the frequency of fatigue failures in drill rods.—B. G. B.

**Contribution to the Study of Secondary Hardening and its Application to Creep-Resisting Steels.** A. Constant and G. Delbart. (*Inst. Hierro Acero, Special Number*, 1955, **8**, Oct., 441–458). [In Spanish]. Since creep resistance is affected by the presence of fine precipitates, and these can be produced in certain steels by secondary hardening, steels susceptible to secondary hardening have been studied and the results applied, with advantage, to the design of creep-resisting steels.—P. S.

**The Hardness of Some Carbon and Low-alloy Steels at Low Temperatures.** R. W. Nichols. (*J. Iron Steel Inst.*, 1956, **182**, April, 348–354).

**The Principles and Development of Devices for the Treatment of Solid and Liquid Metals by means of Intensive Mechani-**

**cal Vibration, with Special Reference to the Electro-dynamic Method.** H. J. Seeman. (*Inst. Hierro Acero, Special Number*, 1955, **8**, Oct., 459–474). [In Spanish].

**Some Experiments into the Behaviour of Plain and Notched Steel Specimens under Static and Fatigue Loadings.** J. W. Fitchie. (*Inst. Mech. Eng., Advance Copy*, 1955, Feb. 21). The elastic and plastic stresses at the roots of semicircular notches in cylinders under static tensile loads are determined experimentally from measured strains, in various shaped specimens of En 36 steel (oil-quenched and tempered). The elastic stresses are in close agreement with those predicted mathematically by Neuber for hyperbolic notches. Experiments under fatigue loadings show that the limiting range of loadings is constant for loadings within the elastic range, but decreases in the plastic range with increasing maximum load of the cycle. The Mises–Hencky function of the three principal stresses is shown to be suitable for obtaining quantitative information relating to the nature of the plastic flow under fatigue stresses.—P. M. C.

**How to Prevent Fatigue Failures.** J. Viglione. (*Product Eng.*, 1955, **26**, Oct., 174–178). A number of examples are given of conditions which are likely to promote failure due to fatigue, and in each case methods of reducing the tendency to failure are discussed. The examples include the effects of surface conditions, temperature, design features, etc.—E. A. C.

**Notch Ductility of Type 410 (12% Cr) Stainless Steel.** F. A. Brandt, H. F. Bishop, and W. S. Pellini. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 3). The factors which influence the resistance to brittle fracture of 12% Cr steels were investigated by Charpy **V** tests and by sharp crack tests of large specimens involving drop-weight and explosion loading. The addition of small percentages of Mo and Ni and the lowering of the Si content resulted in a material highly resistant to brittle fracture at low winter temperatures.—E. E. W.

**The Tendency to Brittle Fracture of Steels as Determined by Yield Stress, Ultimate Tensile Stress, and Reduction in Area at Fracture on Triaxially Stressed Test Pieces.** A. Kochendörfer and C. Rohrbach. (*Arch. Eisenhüttenwesen*, 1955, **26**, Apr., 213–229). The authors use for the determination of the tendency to brittle fracture four types of test pieces with increasing stress-concentration factors. One test piece is used for tensile testing, the others for a notched-bar bending test in a new machine that gives equal moments over the whole length of the test piece. The tests are performed at various temperatures, the results plotted and, from the type diagram obtained, any tendency of a steel to brittle fracture can be concluded.—T. G.

**Effects of Variation in Normalizing and Tempering Procedure on Stress Rupture Strength, Creep Embrittlement and Notch Sensitivity for a Cr–Mo–V and a 17 Cr–4Ni–Cu Steel.** M. H. Jones, D. P. Newman, G. Sachs, and W. F. Brown, Jun. (*Trans. Amer. Soc. Metals*, 1955, **47**, 926–956). The notch sensitivity and smooth ductility for both alloys are greatly influenced by the heat-treatment. High normalizing temperatures, which are particularly damaging to the Cr–Mo–V steel, appear to be independent of grain size at least below the temperature of rapid austenite grain coarsening. Loss of stress rupture ductility in normalized Cr–Mo–V steel is associated with a carbide precipitation which can occur either during tempering or during testing, the latter having the more severe effects.—E. E. W.

**Isoembrittlement in Chromium and Molybdenum Alloy Steels During Tempering.** G. Bhat and J. F. Libsch. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Feb., Section 2, 330–335). The authors present iso-embrittlement curves for a ¾% Cr steel and a ¼% Mo steel in the range 425–680° C. With the Cr steel, there are two distinct regions of embrittlement, at 425–540° C and just below the lower critical temperature, the former being the more pronounced. Two distinct modes of embrittlement are suggested, possibly superimposed at extended embrittling times at 590–620° C. The Mo steel shows little susceptibility to embrittlement at 425–540° C, but considerable embrittlement may occur just below the lower critical temperature.—G. F.

**Temper Brittleness of Some Fe–Ni–Cr Alloys.** L. D. Jaffe. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Feb., Section 2, 412). The author briefly summarizes the results obtained in a study of temper brittleness in Fe–Ni–Cr alloys of varying composition, and indicates the effects of composition changes on the tough–brittle transition temperature.—G. F.

**Systematic Analysis of Wear Problems. I.** G. Saloman and D. A. Beekhuis. **II.** G. Saloman. (*Metaalinstituut TNO, Publ.*, 1955, (27), Jan., 1–12; 1–7). [In Dutch]. The authors evolve a scheme for the analysis of wear problems which has served as a basis for discussions between the members of the Wear Section of the Netherlands Assn. for the Study of Materials. It is pointed out that when discussing such problems the factors of shape, mechanics of the wear system, material properties, wear system conditioning, and human influences require to be taken into account.

**Wear Tests with a Special Sand-erosion Machine.** W. Stauffer. (*Escher Wyss News*, 1952–53, **25–26**, 60–74). Results obtained using a new machine for testing the resistance of steels to erosion by sand suspended in water. This is of particular interest for the selection of steels for hydro-electric turbines. The results of tests carried out on a wide range of steels are given.—B. G. B.

**Evaluation of the Resistance to Wear of Electrolytic Chromium Plating from Indices of Microhardness.** A. V. Shreĭder. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 92–97). [In Russian]. The relation between the hardness and resistance to wear of electrolytically deposited Cr has been studied. The nature of this relation is explicable by those between the hardness of polycrystallites, the strength of their mutual adhesion, the sizes and frequency of cracks, and the Cr grain size. In general, microhardness is a rapid guide to the wear resistant properties of Cr plating.—S. K.

**Recent Studies of Metallic Friction.** F. P. Bowden. (*Chartered Mech. Eng.*, 1955, **2**, Feb., 86–101). The nature and area of contact of solid surfaces are described, and the mechanism of friction due to local welding of microscopic asperities is outlined. Metallic transfer (wear) in engineering operations such as hammering, riveting, turning, etc., is discussed on the basis of autoradiographic detection, and the behaviour of different metals in such operations is compared. The friction of non-metallic solids is next briefly reviewed, and the development of polytetrafluoroethylene (P.T.F.E.), a plastic with very low frictional characteristics ($\mu = 0{\cdot}05$–$0{\cdot}1$), is described. Metals impregnated with P.T.F.E. exhibit very low friction. Methods of measuring temperatures of local hot spots between sliding solids are described, and the problem of ignition by such hot spots of fire damp in coal mines is discussed. The author next deals with friction on snow and ice and quotes improved performance from skis treated with P.T.F.E. Sliding friction at speeds of up to 2000 miles/h is next discussed, and apparatus for studying this problem is described. Friction at very high temperatures, and rolling friction are both briefly dealt with.—P. M. C.

**Impact of Magnetism Upon Metallurgy.** C. Zener. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, May, Section I, 619–630). The author discusses the role of magnetism in various fields of metallurgy, and outlines its influence on phase boundaries, mechanical properties, thermal expansion, and crystal structure. The possible effects of magnetism in future metallurgical developments are considered.—G. F.

**The Conversion of American Wattage Loss Data to $V_{10}$ and $V_{15}$ Respectively.** F. Stäblein. (*Tech. Mitt. Krupp*, 1955, **13**, Aug., 96–97). A graphical method is given for the conversion of American hysteresis loss data in transformer sheet to standard German scales.—L. D. H.

**An Analysis of the Available Data on the Total Heat of Commercial Steels.** J. R. Pattison. (*J. Iron Steel Inst.*, 1956, **183**, May, 64–68). [This issue].

**The Enthalpy and Heat Capacity of Magnesium and of Type 430 Stainless Steel from 700 to 1100° K.** D. R. Stull and R. A. McDonald. (*J. Amer. Chem. Soc.*, 1955, **77**, Oct. 20, 5293). This describes the measurement, using a Southard dropping calorimeter, of the enthalpy of a stainless steel. The various constants and heat capacities are given for temperatures between 700° and 1100° K.—E. E. W.

**Fundamentals of the Use of Vibrations in Metallurgy.** H. J. Seeman and H. Staats. (*Metall*, 1955, **9**, Oct., 868–877). Apparatus for generating sonic and ultrasonic vibration in melts is analysed and new schemes based on electromagnetic generation of container vibration are outlined.—J. G. W.

**Ultrasonic Testing of Welded Joints in High Pressure Gas Pipe Lines.** R. N. H. M. Tychon. (*Gas World*, 1955, **142**, Dec. 24, 1635–1639).

**Ultrasonic Echo-sounding Apparatus for Metal Articles.** Beaujard. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**,

(10), 2013–2021). The method is explained with examples of types of apparatus. The advantages of the impulse echo method are discussed, and details of indications on the oscilloscope are given. Types of commercial instruments are compared.—T. E. D.

**Ultrasonic Transmission Tester Speeds, Simplifies Production Inspection.** N. W. Schubring. (*Iron Age*, 1955, **176**, Aug. 4, 87–90). An ultrasonic transmission tester is described. Usable where both sides of the test piece are accessible, flaws can rapidly be detected due to their effect on ultrasonic conduction.—D. L. C. P.

**Non-Destructive Testing: I. Surface Condition; II. Ultrasonic Testing; III. Radiography.** J. M. McLeod. (*Iron Steel*, 1955, **28**, June, 301–306, 318; July, 339–343; Aug., 397–402). In this critical review of non-destructive testing methods, Part I deals with the static and dynamic surface hardness tests and with the detection of surface flaws by penetrating liquid methods, magnetic particle testing, and magnetic sorting. Ultrasonic testing and radiographic methods are discussed in Parts II and III, respectively, and the principles of the methods, together with their variations, scope, and applications, are described.—G. F.

**Sources of Heterogeneity and Peeling in Boiler Steels.** T. Myslivec and J. Choleva. (*Hutník*, (Prague), 1955, **5**, (9), 263–267). [In Czech]. Causes of and remedies for structural faults in boiler plate are discussed with special reference to recent Soviet publications on the subject.—P. F.

## METALLOGRAPHY

**Applications of the Electron Probe Microanalyser.** J. Philibert and C. Crussard. (*J. Iron Steel Inst.*, 1956, **183**, May, 42–47). [This issue].

**Non Destructive Metallography of Plain Carbon Steels.** K. Sachs and J. D. Bunton. (*Metallurgia*, 1955, **52**, Oct., 205–209). The use of chemical polishing of the surface of heat-treated components enables the efficacy of the treatment to be checked with greater certainty than by any other means. It also reduces the tedious work on specimen preparation. Examples of the use of the technique are described.—B. G. B.

**Simple Equipment Opens Research Door.** R. A. Flinn and P. K. Trojan. (*Mod. Castings Amer. Foundryman*, 1955, **28**, Sept., 62–65). A description is given of two simple microbend testers which enable a metallographic examination to be made on specimens under stress. The specimens, which are thin strips, are bent by a thumbscrew and examined either on the edge where the strain varies continuously from tension to compression, or with the second apparatus, on the under-surface, where the tensile stress is a maximum. To illustrate the application of the technique some results obtained on nodular cast irons with different microstructures are presented and briefly discussed.—B. C. W.

**Tracer Diffusion of Iron in Stainless Steel.** V. Linnenbom, M. Tetenbaum, and C. Cheek. (*J. Appl. Phys.*, 1955, **26**, Aug., 932–936). Using radioactive $Fe^{55}$ the tracer diffusion of iron in 18/8 stainless steel has been measured over a wide temperature range by the surface-activity decrease method. When the grain size is small, grain-boundary diffusion contributes appreciably to the all-over diffusion process, this effect decreasing with increasing temperature.—E. E. W.

**Physical Metallurgy.** A. R. Bailey. (*Soc. Chem. Ind., Reports on Progress of Appl. Chem.*, 1954, **39**, 85–104). Some fundamental aspects of the subject are described, especially those which can be studied microscopically. These include metallographic techniques, deterioration of metal under stress, solidification process in metals, crystallization and structure of cast iron, and solid-state transformations.—E. E. W.

**Determination of Dislocation Density in Deformed Iron.** W. Köster and L. Bangert. (*Acta Met.*, 1955, **3**, May, 274–276). [In German]. The variation in damping was studied in cold-worked iron containing C and N, and a maximum was found at 200° C, which reaches a limiting value as a result of the saturation of dislocations with foreign atoms. Measurements of the saturation concentration permitted the determination of the change in dislocation line density as a function of the amount of deformation.—A. D. H.

**Stress and Distortion at the Interface of Two Crystals.** H. Möller and F. Brasse. (*Arch. Eisenhüttenwesen*, 1955, **26**, Apr., 231–242). Single crystals of mild steel were prepared by a modified strain-anneal method which is described. The orientation of the single crystals was determined by the Laue X-ray back-reflection method. The crystals were cut, ground, and polished and two crystals joined by silver-brazing so that the resulting assembly was elastically anisotropic. The crystal assembly was then stressed and the strain measured by an induction method which uses a length of 1 mm only. The elastic constants of mild-steel single crystals were also determined. The results are discussed in the light of the behaviour of a randomly orientated crystal aggregate under stress.—T. G.

**Experience Obtained with Geiger Counters in X-ray Fine Structure Investigation and in Emission Spectroanalysis.** H. Möller and V. Hauk. (*Arch. Eisenhüttenwesen*, 1955, **26**, Mar., 171–178). U.S. and German X-ray goniometers are compared for use in fine-structure analysis and in X-ray spectral analysis of steel.—T. G.

**Fundamental Structures of Steels.** (*J. d'inf. tech. Indust. Fonderie*, 1955, June, Supplement). A series of photomicrographs of 26 steel structures are reproduced. Details of the etching techniques used are given.—B. G. B.

**Application of Radioactive Tracers to the Study of Diffusion in the Mass and in the Grain Boundaries of Metals.** C. Leymonie and P. Lacombe. (*Métaux–Corrosion–Indust.*, 1955, **30**, June, 231–242). A detailed review of this subject is presented. The Fisher theory of self diffusion is explained and the advantages of radioactive methods for obtaining practical data to test the theory are explained. A description is given of techniques developed for studying self-diffusion and of some of the results obtained.—B. G. B.

**Influence of Polishing Media on the Corrosion Sensitivity of Metallic Surfaces.** W. Weiner and G. Klein. (*Metalloberfläche*, 1955, **9**, Sept., B132–B134). To investigate the influence of polishing materials on the tendency to corrosion of the polished surface, several metals were treated with 5 polishing materials, the surfaces being polished until no visible trace of the medium remained. In the case of steel, sheet treated with iron oxide paste gave the worst results in subsequent corrosion tests, whilst siliceous chalk and alumina were the best media.—L. D. H.

**The "Universal Polishing Paste."** W. Burkart and G. Herbst. (*Metalloberfläche*, 1955, **9**, Sept., B129–B132). The use of $Al_2O_3$ as a polishing medium is discussed. Various types of $Al_2O_3$ are described, with methods of testing and mixing for specific purposes.—L. D. H.

**Electrolytic Polishing of Sections of Thin Samples by Mounting in Plastics.** G. Hildebrand and K. Tikkanen. (*Jernkontorets Ann.*, 1955, **139**, (10), 853–856). [In Swedish]. In this method the plastic mounting for thin samples such as wire is made conductive by the incorporation of well-reduced iron filings, an Al base plate being used to reduce the anode/cathode contact resistance to a minimum. Mounting procedures and test results are described.—G. G. K.

**Some Effects of Metal Removal and Heat Treatment on the Surfaces of Hardened Steels.** K. E. Beu and D. P. Koistinen. (*Trans. Amer. Soc. Metals*, 1955, **48**, Reprint No. 28). The metal removed using either a standard metallographic polishing sequence or a belt sander affected the austenite content significantly to measurable depths below the final polished and etched surfaces and left large compressive stresses in those surfaces. Electrolytic removal of a further 0·005 in. of metal reduced the stresses to zero. Decarburization was studied by means of austenite content, austenite and martensite lattice parameter, and chemical carbon measurements with depth.—E. E. W.

**A New Bath for Electro-polishing Steels.** J. Ibarz Aznárez and S. Feliú Matas. (*Rev. Ciencia Apl.*, 1955, **9**, May-June, 235–237). [In Spanish]. A new, easily employed, polishing bath is described. It is made by mixing equal volumes of $H_2SO_4$ (1·84) and methyl alcohol, allowing the mixture to stand for 24 h, and then diluting by three times its volume of ethyl alcohol. The bath is used at room temperature, with current densities between 0·1 and 0·4 A/cm². The importance of the degree of esterification in the bath is explained.—P. S.

**Etching Processes for High-chromium and Chromium–Nickel Steels for the Determination of Austenite, Ferrite, Sigma Phase, and Carbides.** F. Braumann and G. Pier. (*Arch. Eisenhüttenwesen*, 1955, **26**, Mar., 145–151). The effect of a number of etchants (e.g. methanol–*aqua regia*, orthonitrophenol, Groesbeck's etchant, oxalic acid, and thermal etching) on various phases such as austenite, ferrite, carbide, and sigma in high-Cr and Cr–Ni steels was studied with a view to the separation of these phases. It was, however, found that phase-contrast microscopy revealed these phases quite clearly without etching. Redox potentials were determined on a

18% Cr–9% Ni–2·6% Mo steel in various conditions of heat-treatment and an electrolytic etching process developed for selective attack of austenite–ferrite solid solutions.—T. G.

**Generation of Preferred Magnetic Orientation by Inhomogeneous Stresses in Magnetostrictive Materials.** E. Houdremont and O. Rüdiger. (*Arch. Eisenhüttenwesen*, 1955, **26**, Mar., 153–157). Inhomogeneous stresses produced by slight cold-rolling, machining, bending, etc., perpendicular to the magnetic flux result in preferred magnetic orientation of magnetostrictive materials such as Fe–25% Cr alloy, commercial-purity Ni, and Fe–3·5% Si alloy. In materials with positive magnetostriction preferred magnetic orientation introduced by transversal scratches can be shown by Bitter patterns.

**Loss of Texture in Tapes of a 50 Pct Ni–50 Pct Fe Alloy.** S. Spachner and W. Rostoker. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Aug., 921–922). The authors have noted a sharp change in annealing characteristics of 50% Ni–50% Fe tapes between 1 mm and ½ mm thick, a sharp cube texture being produced in the thicker tapes but no preferred texture in the thinner tapes. Possible causes of the phenomenon are discussed.—G. F.

**Cold-Rolled Textures of Silicon–Iron Crystals.** P. K. Koh and C. G. Dunn. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Feb., Section 2, 401–406). The authors have grown Si–Fe crystals to pre-selected orientations and subjected them to 70% cold-reduction to obtain specimens for quantitative pole figure data. Stable end orientations are determined, and the effect of orientation on deformation behaviour is discussed.—G. F.

**A Stress–Strain Machine for Testing Single Crystals in Alternating Tension and Compression.** M. S. Paterson. (*J. Sci. Instruments*, 1955, **32**, Sept., 356–359). The main points of this machine are: special precautions to eliminate external bending or torsion of the specimen; high sensitivity load and extension gauges; and a special chuck in the form of a mould into which the crystal is embedded with solder to prevent damage to the crystal on gripping. Results obtained with the machine show (i) there is no significant hysteresis inherent in the measuring devices during load cycles, or arising from the solder and cement used; (ii) no creep was found in the solder or cement after several hours' loading.—L. D. H.

**The Maze Domain of Silicon–Iron Crystal (I).** S. Chikazumi and K. Suzuki. (*J. Phys. Soc. Japan*, 1955, **10**, July, 523–534). The surface domain pattern of a mechanically polished Si–Fe crystal was examined by the powder-pattern technique. The pattern was identified as a closure type of domain with zigzag boundaries, and was satisfactorily interpreted theoretically in terms of a 90° wall. Internal stresses up to 360 kg/mm² were found in the vicinity of a scratch, their magnitude being estimated from their influence on the degree of zigzag.—J. G. W.

**The Topography of Solid–Liquid Interfaces of Metal Crystals Growing from the Melt.** C. Elbaum and B. Chalmers. (*Canad. J. Phys.*, 1955, **33**, May, 196–208). An improved technique of separating liquid from the adjacent crystal, used on Pb, Sn, and Zn, has revealed a new structure whose presence depends on crystallographic orientation.—K. E. J.

**Further Observations on Yield in Single Crystals of Iron.** H. W. Baxton and I. J. Bear. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Sept., Section 2, 989–994). Using microscopic and X-ray techniques, the authors have studied the propagation of yield in single crystals of iron in the range 205–295° K. Yielding is shown to occur in two distinct stages, the secondary stage corresponding closely to the Lüders extension in polycrystalline iron.—G. F.

**Pearlite and Bainite Structures in a Eutectoid Carbon Steel. An Electron Microscope Investigation.** H. Modin and S. Modin. (*Jernkontorets Ann.*, 1955, **139**, (8), 481–515). [In English]. Details are given of the structures found in a eutectoid C steel after isothermal transformation at different temperatures. The mechanism of bainite and pearlite formation is discussed. Whereas in previous investigations the microstructures were mainly examined on polished and etched sections by means of the optical microscope, the present study has supplemented this by isolating the carbides and examining both structures and carbides in the electron microscope.—G. G. K.

**Bainite Reaction in a Plain Carbon Steel.** H. I. Aaronson and C. Wells. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Sept., Section 2, 1002–1003). The authors summarize some of the more important preliminary results obtained in a current metallographic investigation of the bainite reaction in a plain carbon hypoeutectoid steel. The results support the theory that bainite results from precipitation of carbides from supersaturated ferrite formed by nucleation and diffusion-limited growth.—G. F.

**Effect of Phosphorus Content on Impact Value of Fully and Partially Hardened and Tempered Mn–Mo Steels.** N. P. Allen and C. C. Earley. (*J. Iron Steel Inst.*, 1956, **182**, April, 375–388).

**Transformation Behaviour and Impact Toughness of Case-hardening Steels.** H. Krainer, M. Kroneis, and R. Gattringer. (*Arch. Eisenhüttenwesen*, 1955, **26**, Mar., 131–140). Time/temperature/transformation diagrams were established for the case-hardening steels 20/5 Mn–Cr, 18/8 Cr–Ni, and *ECN* 15 containing various C contents in the case-hardened zone. Transformation rate increases with increasing C content. The conditions of isothermal process-annealing for complete transformation were studied on 19 plain and alloyed case-hardening steels. Depth of case-hardening in salt-baths depends largely on the composition of the steel; Ni and Cr additions decrease the depth of case-hardening. Impact toughness on unnotched specimen of the 19 steels in various conditions of heat-treatment was also studied. Cr–Ni steels show the highest impact toughness, plain C steels the lowest.

**Investigation of Phase Transformations and Segregation Phenomena in Nickel Steels by Means of Magnetite Suspensions.** K. H. v. Klitzing and E. Wesselhöft. (*Arch. Eisenhüttenwesen*, 1955, **26**, Mar., 141–144). Bitter patterns were used for the study of allotropic phase transformations and segregation phenomena in 28% Ni–3% Cr steels. $\alpha \rightarrow \gamma$ transformation and residual martensite dispersion were established for various temperatures. A steel with 7% Ni and 0·32% C showed Bitter patterns which indicate the distribution of separated zones in the samples, whereas metallographic section did not give any indication of the distribution of separated zones.

**Transformation Studies in Iron–Carbon–Titanium–Vanadium Alloys and the Distribution of Carbon between these Elements.** M. V. Davis and W. P. Fishel. (*Trans. Amer. Soc. Metals*, 1955, **47**, 605–610). A comparison is made of the $Ac_3$ and $Ac_1$ transformations in a number of fully annealed Fe–C–Ti–V alloys with those of alloys of similar composition containing no C. It was found that titanium and vanadium carbides exerted very little influence on the transformation temperatures and that only the Ti and V actually alloyed with ferrite were the controlling factors for the $\alpha \rightarrow \gamma$ transformation.

**Influence of Alloying Elements on the Impact Transition Behaviour of 12% Cr Steels Aged at 900° F.** E. J. Whittenberger and E. R. Rasenow. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 1). The effect of varying amounts of C, Cr, Mo, Al, and Ti on the **V**-notch Charpy transition temperature of 12% Cr steels has been determined. Contrary to published information, the addition of 0·25% did not affect the transition temperature. An addition of 0·5% Mo minimized the increase in transition temperature, while combined Mo and Al eliminated it entirely.—E. E. W.

**Activity of Aluminium in Liquid Ag–Al, Fe–Al, Fe–Al–C Fe–Al–C–Si Alloys.** J. Chipman and T. P. Floridis. (*Acta Met.*, 1955, **3**, Sept., 456–459). Using recent data for the distribution of Al between liquid Fe and Ag at 1600° C, the authors have been able to determine the effect of C and Si on the activity of Al in liquid iron. In infinite dilution in pure iron $\gamma_{Al}{}^0 = 0{\cdot}031$ at 1600° C. Log $\gamma_{Al}$ increases linearly with the concentration of Al, C, or Si. The solubility of C in Fe decreases with Al content.

**Thermodynamics of Carbon Dissolved in Iron Alloys. Part V: Solubility of Graphite in Fe–Mn, Fe–Co, and Fe–Ni Melts.** E. T. Turkdogan, R. A. Hancock, S. I. Herlitz, and J. Dentan. (*J. Iron Steel Inst.*, 1956, **183**, May, 69–72). [This issue].

**The Equilibrium Diagram of the System Aluminium–Iron.** H. W. L. Phillips. (*Inst. Metals, Annotated Equilibrium Diagrams*, No. 13). A large diagram of this system is reproduced together with the references used in its construction.

## CORROSION

**Resistance of Tubular Materials to Sulphide-Corrosion Cracking.** J. P. Fraser and R. S. Treseder. (*Trans. Amer. Soc. Mech. Eng.*, 1955, **77**, Aug., 817–825). A typical sulphide-corrosion cracking failure of tubing in a Sow gas-condensate well is described in detail. A description is given of a test procedure based on the critical stress to cause cracking under controlled conditions, for the rating of alloys as to their resistance to sulphide corrosion cracking. Results are reported of the relative susceptibility to cracking of some commercial tube alloys (0·5% C–0·5% Mo, 5% Ni, and 9% Ni steels).

Significant improvements in the resistance to cracking of the C–Mo steel are reported, effected by a tempering treatment of 30 min at 1100° F after normalizing.—D. H.

**Bolt Materials for Underground Service.** (*Corrosion Techn.*, 1955, **2**, Dec., 370–371). This article is a brief review of a current laboratory study by the U.S. National Bureau of Standards which has shown that some bolt materials can be protected against corrosion by making them cathodic to the structures which they fasten.—L. E. W.

**Corrosion in Singapore—Problems of Packaging and Storage in the Tropics.** P. A. Cartwright. (*Corrosion Techn.*, 1955, **2**, Nov., 362–364, 365). The author discusses the climatology of the tropics in relation to corrosion and the growth of moulds. The preventive steps that can be taken are indicated with particular reference to packaging and to maintenance of radio equipment. The attack of equipment during transit and storage by insects is also dealt with.—L. E. W.

**Corrosion Inhibitors in Petroleum Refinery Service.** (*Corrosion Techn.*, 1955, **2**, Nov., 343–347). The principles of passivation are introduced and then the behaviour and applications of corrosion inhibitors are discussed under the headings (*a*) Anodic Inhibitors, (*b*) Cathodic Inhibitors, (*c*) Organic Inhibitors. Particular attention is paid to the use of sodium chromate, sodium nitrite, glassy phosphates, etc.—L. E. W.

**Corrosion in the Motor-Car. IV. Bearings and Exhaust Valves.** Z. S. Michalewicz. (*Corrosion Techn.*, 1955, **2**, Nov., 334–338). The author outlines the corrosive conditions in which bearings and valves operate and discusses, with particular reference to corrosion resistance, the advantages and limitations of various metals and alloys used for these components.—L. E. W.

**Fretting Corrosion of Mild Steel in Air and in Nitrogen.** I Ming Feng and H. H. Uhlig. (*J. Appl. Mech.*, 1954, **21**, Dec., 395–400). Data are presented on the fretting corrosion of mild-steel cylinders using loss of weight as a measure of damage. Relative slip was measured by use of stroboscopic light and strain gauges and the load was applied pneumatically. The following main conclusions were reached: (i) damage is reduced in moist or dry nitrogen; (ii) debris formed is mainly $Fe_2O_3$; (iii) damage is greater in dry air than in moist air; (iv) metal loss increases with load and relative slip; (v) greater damage occurs at low frequencies for a given number of cycles compared with high frequencies; (vi) temperatures above room temperature produce less damage than those just below it.

**Mechanism of Fretting Corrosion.** H. H. Uhlig. (*J. Appl. Mech.*, 1954, **21**, Dec., 401–407). A mechanism for the phenomenon of fretting corrosion is suggested and the following quantitative expression is derived based on this mechanism:

$$W\ (\text{Total}) = (k_0 L^{\frac{1}{2}} - k_1 L)C/f + k_2 lLC$$

where $W$ = specimen weight loss, $L$ = load, $C$ = number of cycles, $f$ = frequency, $L$ = slip, and $k_0$, $k_1$, and $k_2$ are constants. The first two terms are the chemical factor and the third the mechanical factor in fretting corrosion. The equation predicts that weight loss is a hyperbolic function of frequency, and is parabolic with load and linear with number of cycles or magnitude of slip. The terms concerned with frequency disappear when the chemical factor is suppressed as is the case when fretting tests are carried out in $N_2$. These conclusions are confirmed by the reported data. Remedial measures are outlined based on the data and the proposed mechanism.—D. H.

**Brightening Agents for Tin. II. Sulphate–Sulphuric-Acid Electrolyte.** C. A. Discher and F. C. Mathers. (*J. Electrochem. Soc.*, 1955, **102**, July, 387–389). A stannous-sulphate–sulphuric-acid bath containing N-octyl sulphate and pyroligneous tars from the destructive distillation of saccharides is capable of producing adherent, soft, malleable, mirror-bright deposits of tin.—A. D. H.

**Dissolution of Metals in Aqueous Acid Solutions. I. Current–Potential Relations for Iron and Mild Steel.** A. C. Mackrides, N. M. Komodromos, and N. Hackerman. (*J. Electrochem. Soc.*, 1955, **102**, July, 363–369). Measurements of potential and solution-rate of iron and mild-steel electrodes in HCl alone and with additions of depolarizers are reported and discussed on the basis of the theory of mixed potential.—A. D. H.

**Kinetics of Nickel–Sulphur and Steel–Sulphur Reactions.** A. Dravnieks. (*J. Electrochem. Soc.*, 1955, **102**, Aug., 435–439). The formation of FeS on steel immersed in molten sulphur at 270° C was studied by measuring changes in conductivity of the steel. Frequent failures of the sulphide scale occurred and the kinetics are intermediate between the parabolic and linear. The reaction of Ni with molten S over the temperature range 205–445° C was not accompanied by these repeated failures.—A. D. H.

**High Temperature Corrosion Rates of Several Metals with Nitric Oxide.** M. Farber, A. J. Darnell, and D. M. Ehrenberg. (*J. Electrochem. Soc.*, 1955, **102**, Aug., 446–453). Corrosion rates of several metals were measured by following the change in electrical resistance of a wire specimen at 527–1727° C in atmospheres containing 95% A–5% NO. The metals listed in decreasing order of corrosion resistance are: Inconel, 25/20 stainless steel, Mo, Ni, Ta, 18/8 stainless steel, W, Fe, and Cu.—A. D. H.

**Severe Pitting of Stainless (18–8) Steel in Hot Chloride Dye-Baths.** F. N. Speller. (*Corrosion*, 1955, **11**, July, 31).

**The Passivity of Iron.** K. F. Bonhoeffer. (*Corrosion*, 1955, **11**, July, 32–36). Descriptions are given of the phenomena associated with the passivation and reactivation of iron in concentrated $HNO_3$. Apparent and true passivation potentials and current densities are discussed. Explanations are given of the main passivity and borderline phenomena.—J. F. S.

**Filiform Corrosion Products on Iron Immersed in Brine.** P. F. Thompson and K. F. Lorking. (*Corrosion*, 1955, **11**, July, 37–39). A new type of filiform corrosion pustule has been observed on steel immersed in a refrigerating brine containing a chromate inhibitor. These filaments were secondary corrosion products growing from primary hemispherical pustules on the metal surface. The mechanism of growth of the filaments is discussed.—J. F. S.

**Metallic Materials Resistant to Molten Zinc.** W. Hodge, R. M. Evans, and A. F. Haskins. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, July, 824–832). The authors have studied the resistance to corrosion by molten Zn of several metallic materials, and particularly boron compounds. Coatings were made from Fe–B and Mn–B by welding, hard-facing, and pack-diffusion, the technique of coating being very important, and the results and types of failure are discussed. Sintered compacts of boride mixtures have also been tested, and showed resistance to Zn corrosion at 600° C and to oxidation at higher temperatures.—G. F.

**Use of the Pearson Bridge in Corrosion Inhibitor Evaluation.** E. J. Simmons. (*Corrosion*, 1955, **11**, June, 25–30). The use of the Pearson bridge circuit for measurement of electrode potentials of steel in systems containing corrosion inhibitors is described. Oil-soluble inhibitors which adsorb rapidly give good protection, wheras those which adsorb slowly give variable results.—J. F. S.

## ANALYSIS

**Metallurgical Analysis.** T. S. West. (*J. B'ham. Met. Soc.*, 1954, Golden Jubilee Issue, 261–277). Some selected trends in current metallurgical analysis are discussed. The increasing use of organic reagents for the separation of metallic constituents is first dealt with, followed by an account of the use of complexones in titrimetric analysis and in colorimetry and gravimetry. Recent titrants are then discussed and newer methods of analysis, including polarography, amperometric titration, and chromatography are described.—P. M. C.

**Analytical Determination of Trace Constituents in Metal Finishing Effluents. VII. The Colorimetric Determination of Manganese in Effluents.** E. J. Serfass and R. F. Muraca. (*Plating*, 1955, **42**, Feb., 147–148). A method for the colorimetric determination of 5–50 p.p.m. Mn in the presence of up to 5000 p.p.m. of each of 24 cations involving oxidation potassium periodate is given. A shortened procedure can be used for the range 0·01–5·0 p.p.m. or when the concentration of all other elements is $< 100$ p.p.m.

**The Applications of Spectrographic Solution and Powder Methods to the Analysis of Miscellaneous Samples.** P. T. Beale and D. A. Poynter. (*Metallurgiia*, 1955, **52**, Nov., 253–261). A wide range of materials have been analysed by these techniques which would have proved difficult or impossible to analyse by conventional spark to solid techniques. The majority of samples are non-ferrous metals.—B. G. B.

**The Application of Radio-Frequency Induction Heating to the Determination of Total Carbon in Cast Iron and other Ferrous Alloys.** W. E. Clarke and R. Rew. (*Brit. C.I. Res. Assoc., J. Res. Dev.*, 1955, **6**, Oct., 60–69). The construction of a H.F. oscillator and power supply unit is first reported. The advantages claimed by the technique are: higher working temperature, less wear on the combustion tube, and the use

of a short combustion tube. The results of a large series of tests on a variety of irons and steels are reported.—B. G. B.

**Simultaneous Determination of Carbon and Sulphur.** L. Bjerkerud. (*Jernkontorets Ann.*, 1955, **139**, (10), 847–851). [In Swedish]. In this combined iodometric/titrimetric method the sample is placed in the centre of a quartz-tube resistance furnace and burnt at 1300° C under a controlled $O_2$ flow. The tube is connected with a container for blue starch solution and the change in colour at the start of oxidation is counteracted by adding iodine solution. After complete combustion the gas flows for a further 4 min, during which the colour of the starch solution is adjusted and the amount of iodine employed is read off. The gas mixture, now free from $SO_2$, passes a cooling tube containing NaOH which absorbs CO. The hydroxide solution is led to a beaker and the C content determined by titration with acid. Reproducibility test results are tabulated.—G. G. K.

**Production of Standard Samples and Spectrographic Standard Specimens.** V. V. Stepin. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 381–382). [In Russian]. Progress in the production of standards for use in the analysis of steels and other ferrous alloys is reviewed and the compositions of some are tabulated.—S. K.

**Method of Taking Samples in the Determination of Ferrous and Ferric Oxide Contents in Solidified Slag.** M. Ya. Medzhibozhskiĭ. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 289–294). [In Russian]. The following conclusions are drawn from the results of an investigation of basic O.H. slag sampling: (i) there is considerable oxidation of ferrous oxide during sampling, so that the composition of the solidified sample differs appreciably from that of the furnace slag; (ii) the decomposition of ferrous oxide into iron and ferric oxide is slower than oxidation of the iron by atmospheric $O_2$. A special slag-sampling device to minimize oxidation is proposed, and it is recommended that samples should be taken through the middle door and at least 1 m from the charging door.—S. K.

## INDUSTRIAL USES AND APPLICATIONS

**Metals for Short Time Service at High Temperatures.** A. Levy. (*Mat. Methods*, 1955, **41**, Apr., 117–132). The author discusses the selection problem of materials for severe service conditions of limited duration as encountered in aircraft power plants and rockets. The materials most suitable for turbojet afterburners, ramjet engines, and rockets are dealt with in some detail.—P. M. C.

**How to Select Wrought Steels.** J. W. W. Sullivan. (*Mat. Methods*, 1955, **42**, July, 111–126). The author discusses the factors and properties that must be considered when choosing a steel to meet the requirements of a particular application. Detailed properties are given of steels in the major groups: carbon, alloy, stainless, and heat-resisting.—P. M. C.

**Some Metallurgical Aspects of the Production of Steel Tins.** J. Teindl and D. Zajoncová. (*Hutnické Listy*, 1955, **10**, (11), 654–663). [In Czech]. Economic and technological aspects are discussed, and some improvements suggested.—P. F.

**A Design Guide to Production Characteristics of Engineering Metals.** (*Machine Design*, 1955, **27**, May, 156–205). These articles are intended as a co-ordinated approach directed at one major problem in materials selection and deal with the more common engineering metals:

**Wrought Carbon and Alloy Steel:**

**Drawing Properties.** C. C. Higgins. (158–161).
**Machinability.** F. W. Boulger. (161–166).
**Weldability.** H. Thielsch. (166–172).
**Forging Characteristics.** (172–175).
**Cold Heading Properties.** D. H. Samuelson. (176–178).
**Hot Extrudability.** C. Church. (179–182).

**Wrought Stainless Steel:**

Machinability, Hot and Cold Working, Forging, Cutting and Shearing, Stamping, Deep Drawing, Welding, Brazing, Soldering, Finishing. B. T. Lanphier. (183–190).

**Gray Iron:**

Castability, Section Sensitivity, Machinability, Finishing, Specifications. C. F. Walton. (190–193).

**Malleable Iron:**

Castability, Tolerances, Machinability, Standards. J. H. Lansing. (194–196).

**Cast Steel:**

Castability, Tolerances, Weldability, Machinability. C. W. Briggs. (196–202).

**Cast Stainless Steel:**

Machinability, Welding Procedures, Heat Treatment. E. A. Schoefer. (203–205).

**"Tailor-Made" Steels: Aircraft and Other Industries Make Stringent Demands.** A. M. Hall. (*Iron Coal Trades Rev.*, 1955, **171**, Aug. 26, 501–503). The increasing specialization in demands for materials are being met more and more by the development of steels 'tailor-made' to solve specific problems. The examples quoted by the author include ultra-high-strength steels, low-alloy steels for high-temperature service, low-alloy high-strength steels, special alloys, tool steels, and powder-metallurgy products.—G. F.

**Hot Rolled Carbon Steel Strip.** (*Amer. Iron Steel Inst., Steel Prod. Man.*, 1955, Mar., 1–24). This article deals with (i) some metallurgical aspects, (ii) manufacturing practices, (iii) quality descriptions, and (iv) chemical composition.

## HISTORICAL

**Fifty Years of Progress in Metallurgical Education.** T. Wright. (*J. B'ham. Met. Soc.*, 1954, Golden Jubilee Issue, 111–122). The establishment of metallurgy as a fully fledged independent science occurred very approximately 50 years ago. Progress since the turn of the century in metallurgical education is discussed with reference to its purpose, the growing demand for metallurgical education, the changes in and contents of metallurgical degree courses, and facilities for practical training.—P. M. C.

**Bessemer Process: Centenary of First Decarburizing Patent.** M. Schofield. (*Iron Steel*, 1955, **28**, Oct., 483).

**History of the Norwegian Foundry Industry.** T. Krogvig. (*Giesserei*, 1955, **42**, Sept. 15, 524–526). The history of the casting industry in Norway is traced from the 16th century. A charcoal blast-furnace used in 1800 is illustrated. Cupola furnaces were introduced into Norway a little over 100 years ago. Finally various electric furnaces used in the 20th century are described and illustrated.—R. J. W.

**Smelting Furnaces and Iron Working in Northern Cameroons.** P. Hinderling. (*Stahl u. Eisen*, 1955, **75**, Sept. 22, 1263–1266). The bloomery furnaces with preheated air blast, as worked by native tribes in N. Cameroons, and operating methods for the production and further working of iron are described. A detailed time-schedule of operations, which shows the important part played by stimulating music, is appended.

## ECONOMICS AND STATISTICS

**European Iron and Steel.** Sir C. F. Goodeve. (*Canad. Metals*, 1955, **18**, Sept., 23–26). A ten-year forecast of the development of the European iron and steel industry is presented, special mention being made of important developments in technology since 1954.—B. G. B.

**Steel Industry Efficiency: Effects of Post-War Development Schemes.** (*Iron Coal Trades Rev.*, 1955, **171**, Oct. 14, 881–882). The increasing efficiency of the steel industry is discussed with particular reference to post-war developments effecting economies in raw materials, plant, and labour.—G. F.

**Steel Developments in France: Modernization Plans.** (*Iron Coal Trades Rev.*, 1955, **171**, Sept. 16, 689–690). The main development objectives for the French steel industry up to 1957 are set out, and details are given of home and export requirements.—G. F.

## MISCELLANEOUS

**The French Iron and Steel Industry.** M. Allard. (*J. Iron Steel Inst.*, 1956, **183**, May, 19–21). [This issue].

**Calorimetric Heats of Sorption of Gases on Evaporated Iron Films.** J. Bagg and F. C. Tompkins. (*Trans. Faraday Soc.*, 1955, **51**, Aug., 1071–1080). Heats of sorption of $H_2$, CO, $N_2$, and $O_2$ on evaporated iron films have been measured and the results are discussed.—B. G. B.

**One Hundred Years of Metallurgy at Yale.** (*Metal Progress*, 1955, **68**, Oct., 105–108).

**A New Frontier: Air-Pollution Control.** F. S. Mallette. (*Proc. Inst. Mech. Eng.*, 1954, **168**, (22), 595–628, James Clayton Paper). Activity in the field of air pollution in the U.S.A. has reached tremendous proportions, and is discussed at some length by the author.—P. M. C.

**Sixty-Cycle Induction Heating of Large Steel Sections for**

**Hot Forming. V.** C. H. Hartwig. (*Indust. Heating*, 1955, **22**, June, 1160–1166). The economics of the induction heating process as outlined in previous articles are discussed.—A. D. H.

**Electroplating in Western Germany.** R. Pinner. (*Electroplating*, 1955, **8**, Apr., 131–135; Aug., 277–283, 286). The technical structure of the West German electroplating industry and its post-war status are discussed. German processes and plant for Cr, Ni, and Cu plating and electrolytic and chemical polishing are described.

**Problems of Steel Research.** H. Schenck. (*Z.V.d.I*, 1955, **97**, Oct. 11, 1026–1032). This article consists of a report by the chairman of the V.D.Eh. to the Applied Research Committee of the German Research Association and the ensuing discussion. The research problems of the German steel industry are reviewed against this economic background and there follows an assessment of current resources for steel research. It is concluded that by and large the activities of the V.D.Eh. and of the Max-Planck Institute for Iron and Steel Research measure up to the needs, but there is insufficient contact between universities and industry. The comparative lack of interest of the physics departments in metal physics is singled out for criticism. In the survey of current research mention is made of an investigation of horizontal continuous casting and of a new type of mill proposed by Prof. Platzer of Leoben. A plea is made for an intensification of the research effort in metal physics, thermodynamics, and rheology.—J. G. W.

**Radio-Isotopes in Industry.** (*Mech. World*, 1955, **135**, May, 204–208). The industrial uses of radioactive isotopes either as tracers or sources of radioactivity for measurement and testing are briefly described. A useful list of reactor-produced radioisotopes with their characteristics is given.—D. H.

**The Precipitation of $Fe_3O_4$ in Scales Formed by the Oxidation of Iron at Elevated Temperatures.** J. Paidassi. (*Acta Met.*, 1955, **3**, Sept., 447–451). [In French]. The decomposition of FeO to form $Fe_3O_4$ on cooling was studied. Quenching from temperatures greater than 980° C failed to prevent the onset of precipitation which occurred only during cooling. The instability of FeO is ascribed to the concentration of oxygen in FeO greater than that dictated by stoichiometry. The results are discussed.—A. D. H.

**More Attention to Accident Prevention.** K. Richter and G. Tarnow. (*Metallurgie*, 1955, **5**, July, 229–231). Faulty design of spanners and failure of a lifting drain are given as examples demonstrating the inadequacy, from the point of view of accident prevention, of tours of inspection in factories.

**The Application of Thermodynamics to Fundamental Smelting Processes.** L. Müller. (*Metallurgie*, 1955, **5**, June, 196–202). The results of thermodynamic calculations are used to explain certain metallurgical reactions. The paper is based on two diagrams showing free reaction enthalpy of oxides and sulphides as a function of temperature taken from H. J. T. Ellingham's "Reducibility of oxides and sulphides in metallurgical processes," *J. Soc. Chem. Ind.*, 1944, **63**, 125–133.—L. J. L.

**Application of Statistical Analyses for Quality Control in Steel Mills.** H. F. Myers. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1954, 315–330). The use of elementary statistical methods as a means of obtaining useful information from steelworks data is illustrated, and some of the dangers to be avoided are pointed out. The examples quoted refer to dimensional control, hot-dip coating control, hardness control, tin-coating performance measurement, and special properties of tinplate.—G. F.

**Safety Programs as Stepping Stones to Better Human Relations.** R. Smith. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1954, 331–336). The author outlines the Safety Programme at the Pueblo Works of Colorado Fuel and Iron Corporation, and shows how human relations at the works have simultaneously improved.—G. F.

**The Pulse Counter "AB-017."** J. Kuba and A. Unčovsky. (*Hutnické Listy*, 1955, **10**, (11), 663–665). [In Czech]. An electronic counter designed to work with a Geiger–Müller tube, mainly for metallurgical applications, is described.—P. F.

**Study of the Variability of Thickness of Sheets of White Iron.** J. C. Mathieu. (*Institut de Statistique de l'Université de Paris: Journée de la Sidérurgie*, 1954, June 22, 21–27). Statistical treatment enables the dispersion of thickness of the finished product to be defined. Standards of control can be established which will enable commercial requirements to be satisfied as economically as possible.—T. E. D.

# *BOOK NOTICES*

Li, K. C., and Chung Yu Wang. "*Tungsten.*" Its History, Geology, Ore-Dressing, Metallurgy, Chemistry, Analysis, Applications and Economics. Third edition. (American Chemical Society Monograph No. 94). 8vo, pp. xx + 506. Illustrated. New York, 1955: Reinhold Publishing Corporation; London: Chapman and Hall. (Price 112*s.*).

This, the third, edition of this book, appearing about ten years after its predecessor, continues and extends the original purpose "to present a comprehensive up-to-date exposition of the study of tungsten." Despite the all-embracing sub-title, the geological and mineralogical aspects of the subject constitute a substantial proportion of the contents. Details of the global distribution of tungsten ores together with descriptions of numerous ore-dressing plants are given in the early chapters. Much of the new material relates to developments in U.S. mining, with flow sheets showing a wide variety of processing techniques. The productivity of all the chief mining areas is fully discussed. Although little information is available about the tungsten deposits in the U.S.S.R., the statistics indicate that China remains one of the largest ore-producing areas.

The subject of metallurgical processing is described in terms of the practice prevailing in the larger U.S. companies, and a detailed account is given of a comprehensive range of tungsten compounds.

The chapter on chemical analysis has been greatly enlarged and new methods dealing with the analysis of ferro-tungsten and tungsten carbides have been introduced. Here again, however, the needs of the mining engineer and chemist have been given most prominence, the analytical methods referring mainly to the assay and determination of impurities in ores. One would have appreciated details of the refined techniques by which trace elements, so profound in their effect on properties, might be determined in the pure metal. Spectroscopic methods, now used in many laboratories for routine control purposes, are also omitted.

Other chapters deal with the industrial application of tungsten, including its use in steels, substitutes for tungsten in alloys, and the economics of tungsten.

The text contains such copious references to the literature and to patent specifications that it is essential to apply both critical and selective faculties to a high degree.

There is, alas, the usual crop of printer's errors. Nevertheless, this volume remains a well produced and exhaustive study of the scientific, technological, and commercial considerations relating to a most important metal.—F. E. Poole.

United Nations Educational, Scientific and Cultural Organization. "*Bibliography of Monolingual Scientific and Technical Glossaries.*" (Documentation and Terminology of Science). Volume I. "*National Standards.*" By Eugen Wüster. La. 8vo, pp. 219. Paris, 1955: The Organization. (Price $2.50, 14*s.* 6*d.*, 700 fr.).

In this compilation, the entries are grouped according to the Universal Decimal Classification and, within each group, according to language, the native name being used. Where the language is unfamiliar, such as Magyar or Suomi (Finnish) a translation of the title into French or, occasionally, English is provided. The object of the publication of this list is to make known the glossaries, in whatever language, which contain *standardized* terms, and it therefore only contains those prepared by standardizing organizations; privately compiled glossaries will be dealt with in another volume.—J. P. S.

# *NEW PUBLICATIONS*

American Iron and Steel Institute. "*Index to the Year Books and Regional Papers of the American Iron and Steel Institute*, 1910–1953." Compiled by Jeanne McHugh. 8vo, pp. [vi +] 593. Norman, Oklahoma, U.S.A., 1955: University of Oklahoma Press. (Price $12.50).

American Society for Testing Materials. "*ASTM*

*Specifications for Steel Piping Materials*, 1955." Pipe, Tubes, Castings, Forgings, Bolting. Prepared by ASTM Committee A–1 on Steel. 8vo, pp. x + 409. Illustrated. Philadelphia, Pa., 1955: The Society. (Price $4.00).

AMERICAN SOCIETY FOR TESTING MATERIALS. "*Elevated-Temperature Properties of Carbon Steels.*" (ASTM Special Technical Publication No. 180). Data Compiled by and Issued under the Auspices of the Data and Publications Panel of the ASTM–ASME Joint Committee on Effect of Temperature on the Properties of Metals. Prepared for the Panel by Ward F. Simmons and Howard C. Cross. La. 4to, pp. iii + 63. Illustrated. Philadelphia, Pa., 1955: The Society. (Price $3.75).

AMERICAN SOCIETY FOR TESTING MATERIALS. "*Specifications and Tests for Electrodeposited Metallic Coatings.*" Sponsored by American Society for Testing Materials and American Electroplaters' Society. 8vo, pp. vii + 92. Illustrated. Philadelphia, Pa., 1955: The Society. (Price $1.85).

AMERICAN WELDING SOCIETY. "*Brazing Manual.*" Prepared by a Committee on Brazing and Soldering of the American Welding Society. 8vo, pp. viii + 193. Illustrated. New York, 1955: Reinhold Publishing Corp.; London: Chapman and Hall, Ltd. (Price $4.75, 38*s.*).

"*Argentinien*" [Eisenindustrie]. [Bearb. von:] Walther Lauersen, Klaus Heinrich, Hanns-Jürgen Kunze, Richard Salomon. (Stahlwirtschaftliche Länderberichte, H.I.) 8vo, pp. vi + 90. Kiel, 1955: Institut für Weltwirtschaft au der Universität Kiel gemeinsam mit der Wirtschaftsvereinigung Eisen- und Stahlindustrie. (Price DM. 12.–).

BRITISH ELECTRICAL DEVELOPMENT ASSOCIATION. "*Electric Motors and Controls.*" (Electricity and Productivity Series). 8vo, pp. xx + 279. Illustrated. London, 1956: The Association. (Price 9*s.*).

BRITISH STANDARDS INSTITUTION, B.S. 2643 : 1955, "*Glossary of Terms Relating to the Performance of Measuring Instruments.*" 8vo, pp. 17. London, 1955: The Institution. (Price 3*s.*).

BRITISH STANDARDS INSTITUTION. B.S. 2653 : 1955, "*Protective Clothing for Welders.*" 8vo, pp. 11. Illustrated. London, 1955: The Institution. (Price 2*s.* 6*d.*).

BRITISH STANDARDS INSTITUTION. B.S. 2691: Part 1: 1955. "*Steel for Pre-stressed Concrete.*" Part 1: "*Plain Hard Drawn Steel Wire.*" 8vo, pp. 7. London, 1955: The Institution. (Price 2*s.* 6*d.*).

"*Chile*" [Eisenindustrie]. [Bearb von:] Walther Lauersen, Klaus Heinrich, Hanns-Jürgen Kunze, Richard Salomon, Dieter Anderson. (Stahlwirtschaftliche Länderberichte, H.2). 8vo, pp. vii + 103. Illustrated. Kiel, 1955: Institut für Weltwirtschaft and der Universität Kiel gemeinsam mit der Wirtschaftvereinigung Eisen- und Stahlindustrie. (Price DM. 12.–).

"*The Engineer Buyers' Guide*, 1956." 8vo, pp. 832. London, 1956: "The Engineer." (Price 7*s.* 6*d.*).

FRIEDENSBERG, FERDINAND. "*Die Bergwirtschaft der Erde.*" Bodenschätze, Bergbau und Mineralienversorgung der einzelnen Länder. Fünfte, völlig neu bearbeitete Auflage. La. 8vo, pp. xvi + 562. Illustrated. Stuttgart, 1956: Ferdinand Enke Verlag. (Price DM. 69.–).

GAERTNER, V. "*Electrochimie Pratique. Principes et Technologie.*" La. 8vo, pp. 516. Illustrated. Paris, 1955: Eyrolles et Gauthier-Villars. (Price 2,700 fr.).

GARBOTZ, G. "*Der Kraft- und Arbeitsaufwand sowie die Leistungen beim Biegen von Bewahrungsstählen in Abhängigkeit von den Abmessungen, den Formen und der Güte der Stähle.*" Ermittlung von Leistungsrichtlinien. (Forschungsberichte des Wirtschafts- und Verkehrsministeriums Nordrhein-Westfalen, Nr. 99). 4to, pp. 122. Als Ms. gedr. Illustrated. Köln, 1955: Westdeutscher Verlag. (Price DM. 30.–).

HEINE, RICHARD W., and PHILIP C. ROSENTHAL. "*Principles of Metal Casting.*" Prepared in co-operation with the Textbook Committee of the Education Division, American Foundrymen's Society, Des Plaines, Illinois. 8vo, pp. ix + 639. Illustrated. New York, Toronto, London, 1955: McGraw Hill Book Co., Inc. (Price 56*s.* 6*d.*).

"*Hütte*," des Ingenieurs Taschenbuch. Hrsg. vom Akademischen Verein Hütte, E.V. in Berlin. 28., neubearbeitete Auflag. Bd. 1. "*Theoretische Grundlagen.*" 8vo, pp. xxiv + 1668. Illustrated. Berlin, 1955: Ernst & Sohn. (Price DM. 36.–).

INSLEY, HERBERT, and VAN DERCK FRÉCHETTE. "*Microscopy of Ceramics and Cements, Including Glasses, Slags and Foundry Sands.*" 8vo, pp. xii + 267. Illustrated. New York, 1955: Academy Press. (Price $7.50).

INSTITUTE OF METALS. "*The Constitutional Diagrams of Alloys: A Bibliography.*" Originally compiled by J. L. Haughton, second edition compiled by A. Prince. (Institute of Metals Monograph and Report Series, No. 2). 8vo, pp. 323. London, 1956: The Institute. (Price 35*s.*, $5.50).

KEATING, F. H. "*Chromium–Nickel Steels.*" La. 8vo, pp. x + 138. Illustrated. London, 1956: Butterworths Scientific Publications in association with Imperial Chemical Industries, Ltd. (Price 25*s.*).

"*Kempe's Engineer's Year-Book for* 1956." 61st edition. Edited by C. E. Procter under the direction of B. W. Pendred, editor-in-chief of "The Engineer." 2 vols., 8vo, illustrated. Volume I, pp. 1345: Volume II, pp. 1419. London, 1956: Morgan Brothers (Publishers), Ltd. (Price 75*s.*, two volumes).

KUBASCHEWSKI, O., and E. LL. EVANS. "*Metallurgical Thermochemistry.*" Second edition (completely revised and reset). 8vo, pp. xiv + 410. Illustrated. London, 1956 : Pergamon Press, Ltd. (Price 55*s.*).

"*Metal Finishing Guidebook-Directory*, 1956." 24th Annual Edition. 8vo, pp. 604. Illustrated. Westwood, N.J., U.S.A., 1955: Finishing Publications, Inc. (Price $2.00).

MOTT, B. W. "*Micro-Indentation Hardness Testing.*" La. 8vo, pp. viii + 272. Illustrated. London, 1956: Butterworths Scientific Publications. (Price 42*s.*).

MULLEN, P. W. "*Modern Gas Analysis.*" 8vo, pp. ix + 354. Illustrated. New York and London, 1955: Interscience Publishers, Inc. (Price $5.50).

NATIONAL BUREAU OF STANDARDS. "*Tables of Thermal Properties of Gases.*" Comprising Tables of Thermodynamic and Transport Properties of Air, Argon, Carbon Dioxide, Carbon Monoxide, Hydrogen, Nitrogen, Oxygen, and Steam. (National Bureau of Standards Circular 564, issued November 1, 1955). By Joseph Hilsenrath, Charles W. Beckett, William S. Benedict, Lilla Fano, Harold J. Hoge, Joseph F. Masi, Ralph L. Nuttall, Yeram S. Touloukian, Harold W. Woolley. La. 8vo, pp. ix + 488. Illustrated. Washington, D.C., 1955: Government Printing Office. (Price $3.75).

NATIONAL BUREAU OF STANDARDS. "*X-Ray Protection.*" Recommendations of the National Committee on Radiation Protection. (National Bureau of Standards Handbook 60, issued December 1, 1955. Supersedes Handbook 41). 8vo, pp. vi + 41. Illustrated. Washington, D.C., 1955 : Government Printing Office. (Price 20 cents).

RJABINSKI, B. J. "*Die Planung der Produktion in Hüttenwerken.*" (Übersetzt aus dem Russ). 8vo, pp. 215. Berlin, 1955: Verlag Technik. (Price DM. 25.–).

ROLLEFSON, G. K. (Editor). "*Annual Review of Physical Chemistry*, 1955." Vol. 6. 8vo, pp. x + 515. Stanford, Calif., U.S.A., 1955: Annual Reviews, Inc.; London: H. K. Lewis and Co., Ltd. (Price $7.00, 56*s.*).

RUSINOFF, S. E. "*Foundry Practices.*" 8vo, pp. viii + 261. Illustrated. Chicago, 1955: American Technical Society; London: The Technical Press, Ltd. (Price 52*s.*).

"*Stahleisen-Kalender* 1956." Hrsg. vom Verein deutscher Eisenhüttenleute. Bearb. von R. Arntzen, F. Baumann, I. Beckmann, F. Berghaus, U. Busse, K. Doese, H. Euler, G. Finke, W. Griese, E. Günther, K. Guthmann, M. Hansen, H. Hartmann, H. Kegel, W. Koch, G. Leder, K. Liebschner, E. Loh, F. Marchand, A. Müller, O. Peltzer, A. Ristow, E. Schaefer, W. Schlüter, F. Wesemann, H. Wübbenhorst. 8vo, pp. 324. Düsseldorf, 1955: Verl, Stahleisen. (Price DM. 3.–).

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION. "*Bibliography of Monolingual Scientific and Technical Glossaries.*" (Documentation and Terminology of Science). Volume I. "*National Standards.*" By Eugen Wüster. La. 8vo, pp. 219. Paris, 1955: The Organization. (Price $2.50, 14*s.* 6*d.*, 700 fr.).

VOGEL, RUDOLF. "*Einführung in die Metallurgie.*" 8vo, pp. 169. Illustrated. Göttingen [usw.], 1955: Musterschmidt-Verlag. (Price DM. 22.80).

WIRTSCHAFTSVEREINIGUNG EISEN- UND STAHLINDUSTRIE. "*Statisches Jahrbuch für die Eisen- und Stahlindustrie* 1954/55." 8vo, pp. ix + 243. Düsseldorf, 1955: Verlag Stahleisen. (Price DM. 10.–).

## HERBERT HENRY BURTON, C.B.E., D.Met., F.I.M.

HERBERT HENRY BURTON, who is Director of Metallurgy and Research at English Steel Corporation Limited, Sheffield, was educated at Sheffield Royal Grammar School and King Edward VII School and at Sheffield University.

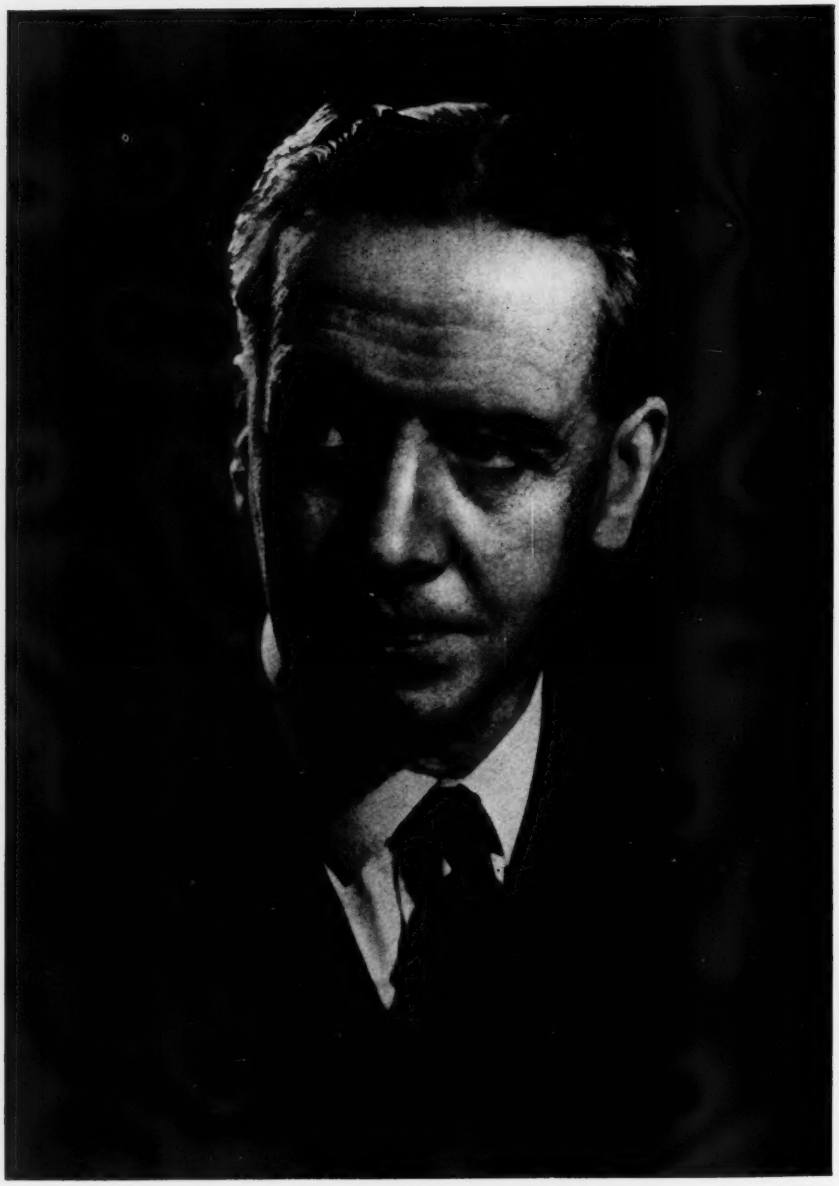
He first joined the staff of the Research Department of Cammell Laird and Company, where he was responsible for a number of investigations, both in the laboratory and in the works. He later became Assistant Superintendent of the Department. After the formation of English Steel Corporation Limited, in 1929, Dr. Burton was appointed Senior Assistant to the late Mr. J. H. S. Dickenson, and succeeded him as Chief Metallurgist upon his death in 1934. He was appointed a Special Director of the Company in 1938 and a Director in 1943. Dr. Burton is also a Director of Firth-Vickers Stainless Steels Limited, of Darlington Forge Limited, and of English Steel Forge and Engineering Corporation Limited.

Dr. Burton was for many years a member of several Joint Committees of The Iron and Steel Institute and the Iron and Steel Industrial Research Council, becoming Chairman of the Ingots Committee and of the Hairline Crack Sub-Committee on the death of Dr. Swinden. Those Committees now form part of the British Iron and Steel Research Association, of which he is a Vice-President. During the war, Dr. Burton was appointed Chairman of the Technical Sub-Committee dealing with gun forgings, and was also a member of the Gun Design Committee, the Metallurgy Committee of the Advisory Council on Scientific Research and Technical Development, the Technical Advisory Committee of the Special and Alloy Steel Committee, and many others. He carried out extensive investigations in connection with steels for guns, naval, tank, and aircraft armour, and steels for aero-engines. He was a member of the Delegation to the U.S.A. in 1943 in connection with the conservation of alloys in steel manufacture.

When the Inter-Services Metallurgical Research Council was formed after the end of the war, Dr. Burton was appointed a member of Council and also the first Chairman of the Ferrous Metals Committee. Dr. Burton took an active part in problems arising from the rearmament plan and the steps which were taken to conserve scarce alloying elements. He was appointed Chairman of the Alloy Steel (Rearmament) Technical Committee, formed in 1951, and was a member of the Metals Economy Committee of the Ministry of Supply.

Apart from these appointments on various committees, Dr. Burton is an Associate Member of the Ordnance Board, a member of the Metallurgy Panel of the National Physical Laboratory, and a member of the Court of Governors and Chairman of the Advisory Committee on Engineering and Metallurgy of Sheffield University. He was elected a member of The Iron and Steel Institute in 1935 and became a Member of Council in 1944. In 1947 he was elected a Vice-President and in April, 1952, he was awarded the highest honour bestowed by the Institute, the Bessemer Medal, for his distinguished services to the steel industry and to metallurgy, with particular reference to the development of alloy steels and of heavy forgings. He was awarded the C.B.E. in the 1952 New Year Honours, and in 1953 received the honorary degree of Doctor of Metallurgy of Sheffield University.

Dr. Burton was elected to serve as President of The Iron and Steel Institute for the session 1956–1957, taking office at the Annual General Meeting on 16th May, 1956.



**Herbert Henry Burton, C.B.E., D.Met., F.I.M.**
**President, 1956–1957**